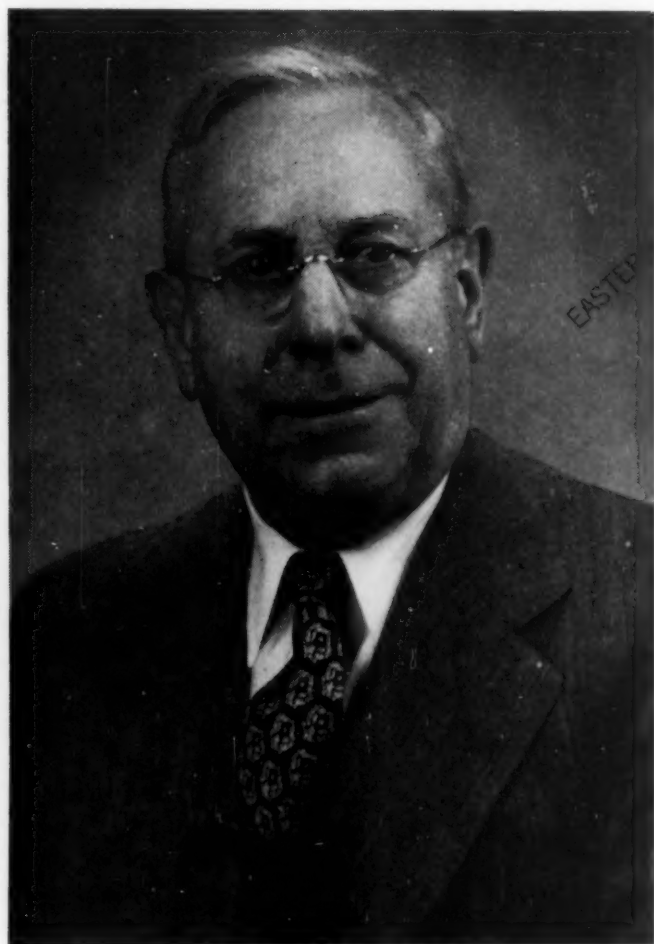


SCIENCE EDUCATION



JOHN ADAM HOLLINGER

VOLUME 44

DECEMBER, 1960

NUMBER 5

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SCIENCE EDUCATION

THE OFFICIAL ORGAN OF

*National Association for Research in Science Teaching
Council for Elementary Science International
Association on the Education of Teachers in Science*

CLARENCE M. PRUITT, EDITOR

*University of Tampa
Tampa, Florida*

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SCIENCE EDUCATION

VOLUME 44

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JOHN ADAM HOLLINGER

To the oldest former officer of the National Association for Research in Science Teaching goes the Twenty-Third Science Education Recognition Award. Of the first eight-year slate of NARST officers, Dr. Hollinger is one of five survivors. Of all present or former members only Dr. Benjamin C. Gruenberg exceeds him in age. In our attendance at early NARST meetings we pleasantly recall the presence and active participation of the then Director of Science Education of the Pittsburgh Schools.

Dr. John Adam Hollinger was born August 16, 1877 at Campbelltown, Dauphin County, Pennsylvania, the son of John and Anne Bomberger Hollinger. On his father's side his ancestors had come to America in 1732 and his mother's ancestors (Peter Bachman) had come in 1718. They were mostly farmers and millers. Three generations of Hollingers lived on the farm on which John was born. Dr. Hollinger's father was killed in an accident when young John was three years old and his mother died three years later. One of his early ancestors was connected with the cloisters at Ephrata, Pennsylvania.

During a not-too-pleasant boyhood, his early education was obtained in a one-room rural school at Derry Church, now Hershey, Pennsylvania. An M.E. degree was obtained at Kutztown Normal School (now Kutztown State College) in 1896. An A.B. degree was received in 1903 from Franklin and Marshall College, Lancaster, Pennsylvania. He did graduate work at the University of Chicago in the summer session of 1908. An M.A. degree was

earned at Teachers College, Columbia University in 1913. A Ph.D. degree was received from the University of Pittsburgh, Pittsburgh, Pennsylvania in 1926. The title of his doctor's dissertation was *The Scientific Preparation of A Curriculum Unit In Natural Science*.

Teaching experience includes: One-room rural school, South Annville Township, Lebanon County, Pennsylvania, 1897-1899; Principal of Elementary School, Dubois, Pennsylvania 1903-04; High school teacher Dubois High School, 1904-05; Head Teacher, High School, Avalon, Pennsylvania, 1905-07; Principal of Elementary Schools, Pittsburgh, Pennsylvania 1907-1919; Director, Department of Science Education, Pittsburgh Public Schools, Pittsburgh, Pennsylvania, 1919-1941; Lecturer, Elementary Education, University of Pittsburgh, 1919-20; 1930-31; Lecturer in Psychology, University of Pittsburgh, 1938-39; Lecturer in Secondary Education, University of Pittsburgh, 1941-42; numerous Extension Classes through the years at the University of Pittsburgh; Summer sessions at Pennsylvania State College (now Pennsylvania State University) 1926 and 1927; University of Denver, summer 1930; Allegheny College, Meadville, Pennsylvania, summers of 1939 and 1940; and Pennsylvania College for Women (now Chatham College) Pittsburgh, Pennsylvania 1949-50.

A partial list of publications include: *Elementary Science By Grades Book 6* (co-author with Ellis C. Persing)—D. Appleton-Century Company, 1930 and 1933; *The Use of Stereographs and*

Stereopticon Slides, N.E.A. Addresses and Proceedings 1929; The Scientific Preparation of A Curriculum Unit In Natural Science (abstract of Ph.D. Thesis), *Graduate School of University of Pittsburgh Bulletin*, 1926; The Church's Education Program, *Reformed Church Review*, 5:329, October, 1926; Perceptual Learning, *Educational Screen*, 19:49, February, 1940; Administration of Visual Aids, *The American School and University*; High School Science, Curriculum and Objectives.

Dr. Hollinger married Adela Shearer Landis, August 18, 1904 at Union Depart, Pennsylvania. One child, a daughter Catherine is married to attorney Ralph H. Demmler and they reside at 1020 Highmont Road, Pittsburgh. The Hollinger's have a grandson and a great-grandson. They are members of the Presbyterian Church.

Past membership in organizations include: National Association for Research in Science Teaching, National Council for Elementary Science, National Education Association, Pennsylvania State Education Association, American Association for the Advancement of Science, Botanical Society of Western Pennsylvania, Pittsburgh Zoological Society, Nature Club of Pittsburgh, and Phi Delta Kappa. Honors include: President, Science Section, Pennsylvania State Education Association, 1927-28; Fellow in AAAS; Director of Pittsburgh Zoological Society; member for 27 years and Chairman of Board of Managers, Gumber School for Girls, Pittsburgh; member of Board of Directors, Hood College, Frederick, Maryland (approximately, 1928-1937); Director, Association of School Film Libraries, Inc.; President XI Chapter, Phi Delta Kappa 1917 (charter member); Executive Committee, NARST, 1933; President, Pittsburgh Lions Club; Past Master, Masonic Lodge; Reserve Militia, Pennsylvania, Infantry, 1918-21; Listed in *Who's Who In the East*, 1942; *Who's Who In Pennsylvania*, 1939; *Lead-*

ers In Education, 1932; *Naturalists' Directory*.

In a brief presentation recently to members of Phi Delta Kappa, XI chapter, upon being asked to respond to "If I Were In Education Again," Dr. Hollinger emphasized a few important items: 1. Basic disciplines in improved curricula, 2. *Stimulating* and *Encouraging* improved standards of achievement, with special reference to the sciences. Quoting Conant, "Some elements of a conceptual scheme which are keyed to human conduct, to moral principles or ethical rules, and to value judgments.", 3. *Self-improvement* should always be a concern for those engaged in education as a serious business, 4. Besides having high ideals and superior behavior, those engaged in education and in research should earnestly strive to assist in Improving the Social Environment with faith in

"That God, which ever lives and loves,
One God, one law, one element,
And one far off Divine event
Toward Which the Whole Creation
Moves."

The Hollingers present address is: Apt. 68, 3 Bayard Road, Pittsburgh 13, Pennsylvania. Dr. Hollinger states that he is now quite active in Western Pennsylvania conservation; is a member of the Citizen's Commission for Public Schools; in the Pittsburgh Lion's Club; in the Retired Teachers Association; in the Masonic Lodge; and in doing a little gardening on the side. The tone of his correspondence shows him to be young in spirit and outlook. The writer has few if any correspondents who can equal him in handwriting, either style or readability. One of Dr. Hollinger's regrets is that the improvements and plans he initiated as Director of Science Teaching for the Pittsburgh Public Schools have not been continued. Dr. Hollinger made noted contributions to improving the quality of science teaching in Pittsburgh. His work as Director made Pittsburgh science teaching known throughout the

country. Upon his retirement the program and plans were allowed to more or less drift along. Similar drifting has happened in other school systems and colleges where changes of administrations have permitted high level attainment in science education programs to either noticeably decline or disappear altogether.

Dr. Hollinger was for twenty-two years Director of Science Education in the Pitts-

burgh Schools. He was among the first individuals to hold such a position in American education, a position which he filled with honor and distinction. It is altogether fitting and proper that the Twenty-Third Science Education Recognition Award should be made to Dr. John Adam Hollinger, a pioneer in American science teaching.

CLARENCE M. PRUITT

SOVIET TECHNOLOGY, AMERICAN EDUCATION AND OUR POST-WAR HYSTERIA *

MARK GRAUBARD

The University of Minnesota, Minneapolis, Minnesota

I

THE educational school year began in the fall of 1957 almost uneventfully. Since spewing forth noble phrases on a variety of social issues, in tones of deeply involved concern, has become a trade-mark of most popular commentators of the air waves, the occasion of the opening of our schools only called forth the usual criticisms. Anything else would hardly be normal. It has become a tenet of our times that the firmest proof of an orator's social consciousness and nobility of vision is strong condemnation of some evil-doer, preferably the government, or else the people, or society at large. There must be a culprit. To become famous as a social critic, one must never reveal and analyze intrinsic difficulties in situations, growing pains, innate confusions, or contradictions. That does not arouse the public nor does it elicit admiration. One must criticize, blame, condemn and moralize, if one wishes to be honored.

And so in the realm of education, our

commentators pursued their usual routine. It seems there has always been a crisis in education and there was one now. There was a shortage of classrooms, our school buildings were old, hence no great ideas could be advanced in them. There existed also a sad, ominous, dangerous, tragic, pathetic, incongruous lack of teachers. And, of course, teachers were underpaid, etc. much of which was true, but hardly to be solved by commentators competing in drama, diction, intonation, and terror.

Of a sudden the line changed. The flight of the Sputnik was announced from Moscow and like a well-trained chorus, our host of famous personalities came up with a new tune. Soviet science has done it again, they proclaimed in emotional notes. The triumphs of the Soviet fission and fusion bombs were nothing by comparison with this new, world-shaking achievement. And they thundered for days, until finally they came up with the culprit and a new barrage of sermons. It is our educational system that is to blame! Johnny can't read, our elementary schools are poor, our science courses are miserable, our high schools are social clubs, our teachers untrained and underpaid, our colleges are playgrounds,

* Based upon address given at Luncheon at Thirty-Third Annual Meeting of the National Association for Research in Science Teaching, Hotel Sherman, Chicago, Illinois, February 13, 1960.

our engineers too few in number, too poorly prepared, and incompetent at best. The Russian school system, on the other hand, was an educational olympia. At ten or twelve the Russian child has had 400 hours of geometry, 325½ hours of algebra, hundreds of hours of physics, to say nothing of literature, art, music, philosophy, geography, metaphysics, and calisthenics.

As luck would have it, said period of rhetorical hysteria happened to coincide with the latest shifts in policies of the Communist International, namely, the much lauded swerve to peaceful coexistence. The Geneva Conference of the Big Powers had taken place two years previously to initiate that new line, and served notice upon the UN and the small powers to mind their business because bigness still ruled the world and made the decisions. Our own press was hopeful but none too loquacious on the subject, but the Soviet press maintained a slightly softened anti-America propaganda in the name of "the Geneva Spirit." After Sputnik, however, our own press and government reacted as if they got a shot in the arm. The phrases—peaceful coexistence and cultural exchange, resounded and reechoed on all sides, followed by floods of talk and comment, as if the hidden sources of cosmic verbal reservoirs had burst open, and as if in accord, American campuses, government agencies, women's benevolent societies, farm organizations, chambers of commerce and cultural and professional clubs rushed to send delegations to the land of scientific progress and technological miracles.

From the numerous groups that went from my home town, there resulted enough reports to supply hundreds of radio and TV talks, and literally thousands of luncheon club and church addresses. Most energetic was the campus delegation among whom only one spoke Russian. The journalists wrote articles, the business and professional delegates lectured occasionally, but most of the time limited their diffusion of information to slides.

Unfortunately, it must be admitted that few people, if any, could gain much from the frenzied wave of pilgrimages. Those Americans who knew Russia from personal knowledge, who like myself, had attended a Czarist school in early childhood, had been in close contact with Russian events and the communist philosophy and had revisited the country in recent years, as I did twice, were obliged to conclude that the upshot of all the post-Sputnik talk of the glories of Soviet science and education vis-a-vis the misery of their American counterparts was both inaccurate, shameful, and harmful.

How could so few wordmongers spew forth so much talk to befuddle so many Americans on at least two subjects on which people had hitherto held fairly sound convictions? The vigor and reputation of America was certainly her technology. America was not renowned for music, poetry, mathematics, painting, or religious lore. Suddenly we were told that America had no engineers, her production was falling behind, 'even though intricate gadgets were choking her homes and cluttering up her kitchens, pantries and garages', her technology was second rate and her educational institutions obsolete and inadequate. Next, America's educational system, an offspring of her pioneering democratic spirit and an institution of which her people were particularly proud, was summarily dismissed as a failure.

Ever since the end of World War II a strange force appeared on our social horizon, to befuddle and confound the American public. Though America and Britain disarmed almost entirely in '46 and onwards, many prominent personalities of press, air waves and campus, accused us of menacing the world by what they called our atom bomb monopoly. Accusations continued to pour forth in spite of President Truman's offer to present our entire atomic development to the UN and to disarm fully, provided we were guaranteed fool-proof inspection as outlined in the Acheson-Baruch report. Dr. Teller and others bat-

tled for years for the hydrogen bomb because it was known that Stalin had set afoot plans for its rapid development by the Soviets. For years, as *Time* puts it, "the US hardly knew what to do with the German rocketeers. The world was again at peace and no Congressman in his right mind would appropriate money for missilery or for Von Braun's dream of space exploration. Von Braun and his men, lonely and discouraged, were set down at Fort Bliss, Texas, left to tinker around pretty much by themselves with old V-2s." (Feb. 17, 1958) But our critics maintained their flood of abuse against any American efforts at modern weapons so as to have some kind of hope for survival. Then came the cry of fallout each time we tested a bomb to free it from useless and harmful radiation debris. Thirty students paraded with posters recently on the Minnesota campus to protest the first atomic explosion by France. Not a single one of these dishonest men had ever protested any Soviet explosion of the "dirtiest" type, nor did anyone else in America, anywhere, at any time. Then came the hysteria over congressional investigations of communism. The cry went up that civil rights were endangered, faculties were threatened, liberties suppressed, a terror stalked the campus. Nations, oppressed by the Soviets and looking to us for aid and solace, were told we were fascistic and that tyranny and oppression prevailed in our land. To this day anyone delving into communist philosophy and tactics is in danger of being called the vilest names and of being speedily ostracized on any American campus. In other words, the last fifteen years marked the heyday of hysterical criticism of America. One upshot of this onesidedness is that if you ask any American student what nations come to mind when the term current imperialism is mentioned, he will cite England, the USA and France, even though our globe is strewn with dozens of nations totaling more than 700 million souls that received their complete freedom from them in the last decade

or so. Conversely, though communism has in the same period brought more than 700 million into national and economic slavery, the enslaving force, the Soviets, are not mentioned.

The reckless condemnation of our educational system is part and parcel of this flagellation in the name of piety and virtue. Yet it is a fact that Soviet Russia did send forth two mighty Sputniks, did follow them with a shot to the moon, and does possess Intercontinental Ballistic Missiles (ICBM) that can travel close to 8,000 miles and with an accuracy of about two miles. It is also a fact that her industry has been expanding rapidly and that there is much that is wrong with our own American educational system. All this is true and yet the harsh criticisms cited above are based on ignorance and, one cannot help adding, some malice. Let us examine the reasons for these assertions.

II

Let us consider Russia first. Her development of the Sputnik was a logical consequence of historically antecedent events, of her ingrained attitude to science and firmly held social goals. Science in Russia, as I shall demonstrate, has a vastly different meaning and function from science in America. While the American attitude is that of viewing it merely as a means of producing consumer goods, of introducing more gadgets and comforts, the Russian attitude to science is much more complex. It rests essentially on four supporting pillars. First and basic is the one deeply rooted in her history ever since the reign of Peter the Great.

The territory of modern Russia was inhabited by a medley of tribes and races dominated by what the Greeks called the Scythians, some centuries B.C. Many waves of invaders passed over that region until the Slavs are encountered around the sixth century A.D., moving southward to the Black Sea and westward toward Central Europe. The western Slavs came under

Latin influence, but the ancestors of modern Russia were Christianized around the year 1000 by the Greek or Byzantine Church. The region possessed cultural centers such as Kiev, Novgorod, Polotsk, and later Moscow, which carried on trade with neighboring states, from Sweden to Mongolia. Recurrent invasions from neighboring lands and endless wars plagued these states ruled by princes. But early in the 13th century the Mongol leader, Genghis Khan, won mastery over the Orient and later his grandson, Batu Khan, swept over Russia. The peoples of the conquered territory paid tribute to the invaders and lived in awe and terror of them though the Tatars permitted them some independence in commerce, trade, and their Orthodox faith. Thus the Russian peoples were insulated from any Western influence while into the future culture of that vast land there seeped a mighty heritage of Tatar autocracy, worship of the state, brutality, and a sense of the sacred insignificance of the individual.

Moscow emerged as a conspicuous princely state in the middle of the 12th century. It was somewhat favored by the invaders, prospered under their dominion and gained in authority over other subject Russian states. By the end of the 14th century, Tatar power had begun to wane and the Muscovite princes began not only to defy them, but even won some open battles which Moscow ventured to wage against them. In taking this lead against the Tatars, who were additionally weakened by the threat of the Turkic conqueror Tamarlane from the East, Moscow gained power over the Russian states and began to unite them against the Lithuanians and the Poles from the west. Under Ivan the Great (1462-1505) Moscow expanded, her prince began to call himself Czar, or autocrat, his powers grew, a feudal nobility of Muscovites was planted in conquered states, with serfdom as its after-effect. Thus the future empire was founded. Under the reign of his grandson Ivan the Terrible (1533-1584) the process was completed with

terror against any member of the arrogant nobility or the meeker classes that wavered in submission. Ivan brought about the kind of law and order befitting an absolutist realm and began the expansion of Russia by knout, gun, sword, and slaughter which in a few generations made it the largest contiguous empire the world had ever seen, extending from the Baltic to Alaska.

Of the great cultural growth that occurred in Western Europe in the late middle ages and early modern times, Russia knew only a little until the reign of Peter the Great (1672-1725). Tsar Peter adored science, especially technology. He was painfully aware of Russian backwardness and was determined to eliminate it. Russia must be a power among equals, and the arena of power and history was in the West, where science was its secret weapon and motive force. Science to him meant literally power, as it did rhetorically to Francis Bacon. He loved artillery, hence respected mathematics; was intrigued by fortresses, hence adored engineering; and he was fascinated by ships and naval science. To be a power like England or Holland, Russia must have ships and navigators. After his mother's death Peter went abroad, the first Russian ruler to do so, worked as a laborer in an Amsterdam shipyard, visited the famous microscopist Leewenhoeck, Isaac Newton and other scientists, collected compasses, anchors and all kinds of gadgets, recruited scientific workers and scholars, and inspected dozens of institutions connected with applied science. He returned home to continue his lifelong war with Sweden and the Turks. He fought both victoriously by land and by sea. He pushed the Swedes beyond the Baltic, founded St. Petersburg and built a navy by forced labor, firmly suppressing any opposition. He consulted with Leibnitz and brought to Russia a host of foreign technicians and craftsmen. He founded the Russian Academy of Science in 1724-25, consisting of twenty-eight members, of whom twenty were Germans. Attached to the Academy was a Gymnasium

and a University, both slow in starting. Men of the caliber of Euler, Bernoulli and Delisle, were later brought to Russia, and Peter himself soon came to respect research above all else. He also respected western ways, forced Russians to shave off their beards, ordered western dress, founded a state system of popular education, a School of Mathematics and Navigation (1701) with instruction in English, a Naval Academy (1715), a series of technical schools known as Cypher Schools (1714), largely technical institutions aiming at supplying the government with semi-skilled technical workers "acquainted with arithmetic, geometry and geodesy," founded lay schools attached to the Navy Department, and also reformed and improved existing clerical schools. Avidity for science thus entered the Russian national conscience in an openly sanctioned and forceful manner. Nor was it the whim of one autocrat only. It found support in many enlightened Russians, some close to the leadership of the nation, the nobility, government officials, the intelligentsia, and the merchants. It became an integral part of the Russian culture and was closely linked to Russia's deepseated sense of inferiority toward the West, the West that had the science she needed, the philosophy, culture, technology, art and wisdom. Russia was behind, it was steeped in poverty on the social front and in faith and superstition on the cultural. Its maturation had been held back by the Tatars, by its own backwardness, and by its geographic remoteness. The time had come for her extrication from stagnation, for "catching up with the West," for becoming an equal among the enlightened powers on earth, equal industrially, militarily, culturally, artistically and diplomatically. With the fall of the Mongols in the East, and with China's old luster fading rapidly, the center of the world was obviously in the West and Russia must play there her role as an equal. Westernization and modernization thus became a force in the culture pattern of Russian thought.

From the reforms of Peter the Great, this stream flowed resolutely forward, at times smoothly and with the support of the autocratic throne, but at other times bitterly resisted by Tsar, Church, and police. There grew up a genuine ambivalence toward the idea. Progressive rulers such as the cultured, amoral Catherine the Great, her grandson Alexander I, the friend of Voltaire and adversary of Napoleon, Alexander II, his grandson the liberal Tsar and emancipator of the serfs, and to a very small extent, the weak and vacillating Nicholas II, the last of the line, all sought to modernize Russia and pull her into the family of Western Christian nations. On the other hand, the intervening successors of each but the last, pulled in the opposite direction. They feared French Enlightenment and science, because they believed correctly, as it proved, that these novel luxuries meant the intrusion of democracy and perhaps the ultimate destruction of their cherished autocratic, tyrannical rule which would surely spell the end of the Russia they knew, and which they were determined to retain. These were the desperate, ruthless defenders of reaction in all its forms, conspicuous among whom were Nicholas I, Alexander III and to a considerable extent, the hapless Nicholas II.

But regardless of the vacillation of her rulers, the small but vocal intelligentsia of Russia, that contrary to the Marxist and the Hitlerist dogmas recognized no class or race lines but sprang from all groups and nations within the Tsarist empire, remained true to its hunger for modernism, science, culture and the liberation of the spirit from the bonds of church and even faith. To this intelligentsia the West remained the model of the good life, the free and learned society, the Eden of the mind in liberty, mental growth and cultural self-realization. There was a very small opposing minority of men loyal to the traditions of old, which, except for Dostoyevsky and a few minor men in literature, had little influence. This group put its faith in monarchism, Slavophilism,

orthodoxy, traditionalism and often mysticism. By and large, however, the leaders in Russia's literature, art, science, serious journalism and above all the universities, were guided, if not controlled, by the admirers and apostles of westernization, with science as the holiest of its patron saints, the hope and light of the world.

The second pillar of the meaning of science in the culture pattern of Russia derived from Marxism. The basic tenet of this mid-nineteenth century philosophy was materialism. It worshipped science and the scientific method. This faith declared that ideas and beliefs, all philosophical, moral, social and ethical concepts were determined by the tools used in production. These tools were in their turn determined by the science of the day; hence science ruled the entire social fabric. In the minds and hearts of Marx and Engels as well as their followers, science occupied a unique pew. It was not only the foundation of society through determining its productive tools which in turn molded its ideas and values, but science was the mental and intellectual dynamite with which to destroy all faiths manufactured and favored by the capitalist system. It thus had the power to liberate the spirit of man from all its opiates. Not only was science regarded as a revolutionary force, but every scientist was regarded as an active worker for the Revolution. If a particular scientist happened to be politically conservative, he was merely put down as a freak, an anomaly, much as a mother of a newborn infant that for some strange reason had no milk for feeding it.

The bulk of Russia's intelligentsia was revolutionary, which meant at the time that it believed in democracy, rationalism, social justice, free education, free elections and was against censorship, serfdom, tyranny, and orthodoxy. Hence the intellectuals came in time to be attracted to Marxism. Many native scientists were also revolutionary and even Marxist. Contemporary Russia proudly lays claim to many outstanding scientists of the past as true

precursors of present day communist ideology.

Both Marx and Engels wrote on science, and so did Lenin and Stalin, and even Khrushchev. Every Marxist considers himself a major or at least a minor authority in science. Marx begged of Darwin to honor his *Capital* with an introduction; Engels is to this day honored by many left-wing British and American professors as an authority on the philosophy of science by virtue of some loose notes he threw together on topics related to science. Lenin's word is still law in science and is regarded as more sacred than any papal decree by more people than honor the Catholic credo, by virtue of his journalistic work called *Materialism and Empirio-Criticism*. Stalin's concern with science is evidenced not only by his numerous pronouncements on every science he could put his rhetoric to, but by the lives of dozens, if not hundreds of outstanding scientists which he snuffed out in cruel purges before and after World War II.

But of significance to our story is the fact that every Marxist regards science with reverence, worships its priesthood and sees in it the salvation of mankind through its service to mass production and its aid to the formation of a centralized economy. It is a weapon for social change. A scientifically geared centralized managerial government will of necessity be one in which they, the Marxists, will draw up the plans, lay down the rules, press the buttons, and punish offenders. Secondly, science is intellectual manna, the hope and nourishment of the soul, now that faith in God was no longer needed or fashionable. It was the light of the liberated mind, the key to the real truth and the essence of genuine materialist, verifiable knowledge and wisdom. It was looked up to with equal adoration by the mass following of the Marxist philosophy. Trade Union halls in Europe, in the early days of the socialist movement, held constant lectures on science and sold scientific pamphlets cheaply printed in large

numbers. Socialist leaders urged their followers to visit museums and all knew that science was the true faith of the new movement.

The third pillar upon which rests the Soviet attitude to science was erected by communism-come-to-power, hence was the work of Lenin and Stalin. Directly after the overthrow of Russia's first democratic government under Kerensky, Lenin realized that things had gone wholly awry with the Marxist historical scheme. Thus its most pious adherents found themselves in control of a backward feudal state rather than an advanced industrial one, as Marx had predicted. To rectify this error of fate and history, and to retain sweet power with its freedom to kill opponents and build the kind of managerial society Lenin wanted, science was called upon to fix up matters and speedily industrialize the country so that, as the Bible says, the words of the Prophet come true. Industrialization and mechanization became the life-blood of the new society; tractors and factories the goal of life.

The new goals were best expressed by Lenin's famous dictum inscribed in electric lights on the enormous Dnieprostroy Dam: Electricity + Soviet Power = Communism, meaning science, or power over the material world, combined with the subjective wisdom of the dictatorship of the communist party, will bring about the perfect and just society, which is communism. Thus, science became the immediate aim of Soviet life, the motive power of the successive Five Year Plans, the practical tactics of the hitherto merely dreamed of and talked about Marxist scheme.

After World War II, Stalin completed the framework for the role of science in Soviet culture by making his own and final contribution. He had seen the Nazi war machine in action. He was obliged to run away ignominiously from Moscow and watch much of Russia feel the scourge of war in spite of the unspeakable treaty he had made with Hitler and all the aid he had extended to the Nazi war machine in the

hope of dividing the spoils between the new partners as they had done in Poland and around the Baltic. He was determined that never again would Russia be invaded and laid waste, and never again would communism be exposed to the shame of having her armies surrender wholesale to the tune of four to five million men, as they did, and to a despicable enemy like Nazism, at that. Moreover, Hitler was dead, Britain and America were frantically demobilizing and disarming, their leaders were politically naive, hungry for peace and chrome-plated cars, and divided in their councils. This was the time to prepare for "the final conflict," declared Stalin, and in his famous speech of February 9, 1946, announced the new slogan, "Back to Revolution." The communist goal of world conquest is within reach, he declared, and all that is needed for the militant working class, meaning by it the Soviet Government, is to arm, propagandize, destroy the good name of the democratic nations, single them out as warmongers, oppressors, colonizers and exploiters, proclaim to the world that they possess no real democracy and no freedom, and above all prepare and prepare, with the best, the latest, the most modern weapons that science can offer!

Upon this foundation was erected the vast program for nuclear bombs and missiles, beginning early in 1945. As usual under Soviet rule, the programs were secret and money was no object. The best men in the country were assigned to these special tasks and qualified ones were grabbed and gathered from every conquered territory in Europe, particularly from Germany. Any individual connected with the V-2 rocket project, anyone possessed of experience and skill related to atomics and missiles, was deported and cajoled or coerced into the new projects. Under normal conditions, as is common knowledge, the Soviets copy every patent, every model car, engine or radio that appears in the outside or capitalist world. Their vast economic espionage system obtains any information of value,

whether secret or not, through numerous channels, but most particularly through the communist party of each country and their hordes of sympathizers. Thus it transpired that by 1946 Russia had a pretty good head start in the fields of both nucleonics and missiles, while the United States was badgered by hundreds of parades against atomic armament, against any defense at all, had squabbles over budgets, heard speeches by J. Robert Oppenheimer about sin and the immorality of research on the hydrogen bomb, and was treated to impassioned articles in the *Bulletin of Atomic Scientists* by Norbert Wiener and others, calling on scientists not to aid in defending the U.S.A., democracy, or the nation in general. In Soviet Russia there were not only no *Bulletin* articles, no parades, no espionage, no fifth amendments, no opposition to investigations, no haggling over budgets, but whatever scientists or engineers were needed could be easily skimmed off the top group of brilliant graduates and known men of talent could be promptly placed where needed since all men are employed by and are at the mercy of an autocratic government.

All one can say is that given the possible advantages for getting results that prevail under the Soviet system and its parties all over the world, one is surprised that it took the Russians as long as it did to reach the hydrogen bomb or the Sputnik. It is also most amazing that the United States released a functional missile so soon after the Russians released theirs.

Did Soviet education have anything to do with the attainment of the Sputnik? The answer to this question must obviously be in the negative. Only sheer hysteria could cause many Americans, otherwise competent, gifted and brilliant, to think differently. To clarify this point let us take a look at education in old and new Russia and then answer the obverse of the same question—Is American education responsible for our failure to be first with an earth satellite, or

to catch up with Soviet advances within two or three years?

Russian education did not fare too well on the elementary level after the bold steps taken by Peter the Great. His plans were too ambitious and the people were not ready for them. But the Academy he and his wife Catherine I had founded did become from the start a functional and going scientific concern and a center of intellectual stimulation. It was not an academy in our sense, but a working organization supported and guided by the state, as it still is to this day. Already in 1740, its secretary stated its aim to be "to discover new truths in their specific sciences and serve the government with their discoveries." Also, by that time, the Academy had begun to include more and more Russian members, and by 1747 the Academy had a good number of both regular and honorary members. These were expected to have western works of high scientific merit translated into Russian and also "work on special requests emanating from various government agencies." It did carry out its stipulated task "to introduce and acclimatize science in Russia", and by the end of the 19th century the Academy had grown to full maturity and honored many outstanding foreign scientists.

Soon a university and a high school, or gymnasium, were formed in close association with the Academy, although "the first real Russian University" was only opened in Moscow in 1755 and proved more successful. Prior to World War I Russia had only nine universities but all of them were of high caliber both in staff and standards, all of them the equal of the best German universities after which they were modelled. In 1916 these universities had a total enrollment of 35,695 students, while other institutions of higher learning, mostly high technical schools, had approximately 50,000.

Popular education initiated by Peter, grew very slowly in Russia as it did elsewhere, because it depended upon public and

official attitudes and values, and therefore seems to require time. Its cause got a great boost under Catherine II but received setbacks under the reactionary Tsars who feared the West and its democratic notions.

In the year 1914 the Russian universities had 46.4 per cent students from the gentry, officials and clergy, 15 per cent from "merchants and citizens," 24.3 per cent workers and artisans, and 14.5 per cent peasants. Technical state institutes showed for the corresponding groups 27 per cent, 19.1 per cent, 31.6 per cent and 22.4 per cent. Hence the university student body was 40 per cent of worker and peasant origin, while in the higher technical schools it was 54 per cent! Outstanding students were rewarded with fellowships for foreign travel, and every institution had a high ratio of good scholarships with indigent students exempted from fees. Numbers of scholarship varied but reached apparently more than 50 per cent. According to Ignatiev, an ex-minister of education, "53 per cent of all Russian university students were impecunious," but at Dorpat that figure stood at 83 per cent, at St. Petersburg 72 per cent for male and 82 per cent for female students.

The universities were democratically run with the highest administrative officers elected by the faculty including the appointment of professors. The University Council was the real governing board. The student body was radical and constituted the sole militant force in the country openly pitched against the government. Students were always at war with the police and the police with them. Thousands were arrested annually, and in some years thousands were deported to Siberia. They were not only western and materialistic in their outlook, but revolutionary, nihilist and devotees of direct action. Universities were sometimes shut down altogether in reprisal for riots for periods of many years. The people regarded the students and faculties of the universities, but also to some extent of the

gymnasia, as the vanguard of progress, the priesthood of the new learning and fighters for reform.

Education in general came to occupy among all the people of Russia a place of distinction, and was viewed with awe, respect and envy. I myself went to a free Tsarist school from the age of nine to eleven and well remember that in our town in Russian Poland, a family was held in the highest respect not because it had money, could boast of a famous ancestor, or was titled. What elicited true honor was the fact that the family's son was the first in his class. There were no sports or extra-curricular activities of any kind. The average citizen tipped his hat to a high school teacher, and university students wearing their capes and uniform caps, regarded themselves as the true autocrats of the spirit. Education was highly selective and aristocratic, and the students and public knew it. Going to school was not a "natural right," as it is in America. Beyond the free school that carried one to the thirteenth or fourteenth year of age, one had to pay. School was attended six days a week and homework consumed four to five hours daily on the average, and often even more than that. The work was hard, and playing or relaxing was out of the question. The kindest of mothers would not dare sentimentalize over the invariant duty of the student, boy or girl, to do his work after coming home until it was completed, be it ten or eleven in the evening. The spectre of flunking out hung like a demon over every student's head. It kept the parents in constant terror. Upon discovering that their child was studious and capable, they felt relieved and never weakened in their gratitude, and thanked God in their daily prayers. Going to school was a privilege and the student was indecent if he abused it by not performing his duty. He owed it to himself, his family, and his country to study and win a gold medal if possible, but under all circumstances to pass. He was preparing

himself with the aid of the state to serve that state because every high school graduate could at least qualify for employment with the government. It must be borne in mind that Russia was not developing very rapidly until about three decades or so before the Revolution and non-government opportunities were not too numerous before that period.

Strange, that in spite of the intense anxiety about education students acquiesced in their fate when they flunked out. The country not being a democracy, there was no pressure on the part of the public to lower standards, as there is now in France, India and elsewhere, and there were no signs of increased hostility, either to society or the government, on the part of those young men who failed and had to go into the army and be kept away from the goals they had dreamed of reaching.

Let us now compare this scene with the American situation. To begin with, science in America is not the sacred cow it is in Russia. To us science means pragmatism, the power or skill to make more gadgets and produce more consumer goods. Science means TV, radio, penicillin, jet planes, and electronics. The philosophic, salvationist, pure-wisdom auras around it are missing. Prosperity means endless catering to our offspring, showering them with gifts, luxuries, and rights. The child is king and master. Its comfort, fun, and freedom is the goal at home and in school.

Further, our own system of popular education reached full development at the same time as did the Russian system under the Tsars, in the second half of the nineteenth century. Around the turn of the century only a very small percentage of our public elementary school graduates attended high school. Today more than 50 per cent of the nation's youth attend high school. Of the number that enter high school close to 50 per cent go to institutions of higher learning, with close to 70 per cent completing them. Each state in the Union

has a people's university to which every high school graduate with an average grade of C, or thereabouts, must be admitted. The bulk of our university graduates come from such institutions and a lesser segment from equally democratically controlled religious or quasi-religious colleges. All our public schools are run by the people and aim at preparing the student for life within the belief frame of the community and its educational leadership. They are not operated by an independent, autocratic bureaucracy which gets its orders from a higher agency such as the Tsar's ministry of education, or the commissariat which carries out the dictates of the Presidium of the Communist Party.

Most people find it difficult to concede that concepts and institutions have consequences independently of their initial purposes. A democratic educational system brings consequences in its trail which may not necessarily be good simply because democracy is good. Similarly, the birth of an infant is a wonderful event to its parents, but some infants may later on give them much concern or bring nothing but anguish. In other words, intentions are one thing, putting them into effect another, and the further impact of those effects, still another matter.

The facts so far seem to indicate that within a democratic system of education operated by the people, there invariably occurs a reduction in standards. Let us examine the data. Bear also in mind that the American democratic society is prosperous and growing more so from year to year. With prosperity comes even more democracy since each individual grows in self-importance and expects to be catered to more and more. He has "natural rights" of all kinds. If he does not earn as much as the other fellow, he expects subsidies. Being humanitarian and socially-minded, a democratic society values and honors the individual above all else, is sympathetic to the handicapped and the less gifted. By

virtue of the small number of fortunate and gifted individuals within the normal distribution curve for any human capacity, a non-aristocratic educational system must have lower standards than an aristocratic or selective one. If every American child, or even 80 per cent of such children regard it as a "natural right" to have a high school diploma, how can that diploma be kept from them? And how can that diploma represent the same high standards as one given to members of a highly selected group? What high school principal in a small American town, or even in a big city, can or wants to withhold graduation from a boy whose family he knows and whom he does not wish to hurt? Why should he do that? It is only a high school diploma, he figures, and means nothing in a society in which everybody can and should have an education as a matter of course. Let the university keep him out, since that institution is supposed to be selective.

Also, why should a high school English teacher flunk or hold back some troublesome student whose family is determined to keep him in school until he is eighteen, because it pays taxes, believes that its son is as good as the next boy, really has a good head but is a little lazy, or has a few bad friends? If the teacher flunks such a poor student, he will simply have him again next year to plague him with a double dose of venom and resentment. Whom is he hurting by passing him? He is not undermining either society, democracy, or education. Let the boy graduate then, since it is only high school. What difference does it make? After graduation he will go to work and make a good salesman, or whatever you will. If left back, he will learn nothing anyway, his parents will protest to the PTA or the legislature, and bring up all sorts of complaints. Why risk it? Besides, what threat can a school hold over reluctant students who are uninterested or hostile and know they are in school because they are forced by law to be there, or by their par-

ents, and will never develop a liking for booklearning and are not concerned about careers in any field requiring study?

Also, a prosperous, materialistic and free society like that of the United States does not seem to evolve as great a respect for learning as do European cultures where education is often the sole opportunity open to men of ability. In some of the Old World countries opportunities in business, politics, diplomacy, acting, advertising and other fields, are too narrow, too tradition-bound or limited, to attract the youth. In America the entire social horizon is open and education is not the sole path leading to the alluring goals that glitter beyond. Hence in Europe education is still an inspiring goal, an opportunity, an open avenue to success. In America there are so many other roads, and the goals of life have become the acquisition of material goods, the gaining of all kinds of securities and extended individual freedoms. Our slogans have become: Nobody can do anything to me, Nobody can tell me anything, No one has a right to demand anything of me whether national survival is at stake or not. If your Congressman or Senator does not get you the things you want, throw him out and vote in a man who will. Needless to say that with such an outlook one does not honor education for its own sake, one is not willing to accept discipline and discomfort for the sake of learning, for the national good, or for the sake of national survival. No wonder all the cultural and campus leadership is strongly opposed to a formal loyalty oath or to any oath, and the term patriotism nowadays only elicits laughter.

This means that we pay a price for democracy and for obligatory popular education. Apparently, we cannot have our cake and eat it. The successful artist loses the romance of the attic, the successful pioneer finds himself mayor of an established but dull town, the romantic lover may

suddenly discover himself in the role of a harnessed or even henpecked husband.

The truth is that even college standards must come to suffer. If all high school graduates with C averages are admitted to a state university, the college instructor, unless he is really tough and brutal about it, is tempted to conjecture: Why should I bother failing too many, hurting them and getting myself into trouble over an intangible, fine line of demarcation? This student hovering in the lower zone of a C or a D will not build a bridge that might collapse, nor will he endanger a patient on the operating table. He is only at college; let the professional schools flunk him out. The fact is that the public accepts nowadays the necessity for strict selection to professional schools but not to college. As if to demonstrate the actual trend and genuine kindness of a truly democratic society, many state universities now have General Colleges for high school graduates who have failed to obtain a C average!

The real problem that confronts a democracy and will plague it for centuries to come, if it survives the onslaught of communism, fascism, and other forms of managerialism, is how to develop social goals other than equality and material comforts, how to make people more willing to forego individual demands for the social good, how to raise the prestige of learning and spiritual and cultural values for their own sake, how to honor those that excel in intellectual ability, how to strengthen morality free from pragmatic objectives, and last, how to strengthen desire for education so that the student will eschew fun and resist the call of his many sirens, such as the car, dances, parties, dinners, celebrations, vacations and other distractions to which the materially less-blessed European youth is as yet unexposed.

Had the sudden rash of vociferous critics of American education addressed themselves to this problem, they would have been constructive and sincere and not the futile, fly-by-night critics they were in

actuality. Democratic education is a new experiment in history, and as we saw, is beset with serious obstacles. Nobody claims it is perfect. How can it be, in view of its problems? Much, however, can be done to limit the freedom of selection of subjects for the sake of one's ease and pleasure, establish a more demanding atmosphere, curb the evil effect of the "natural right" slogan, raise the prestige of school and teacher, and the social status of education and cultural values as such. But have the fly-by-night critics really spent many tormenting hours grappling with the real problem before attacking the public with their rich verbiage and facile remedies? Most of them were totally ignorant of the problem as it exists both in Russia and in America. Their cries of abuse were simply part of the general post-World War II disease among the American intelligentsia whose symptoms are to attack anything which is American, to denigrate and criticize our society as a whole and oppose national defense. Observe the venom with which it attacked Congress when it wished to understand the nature of the enemy that killed 35,000 of our boys in Korea, berated our people and our institutions without letup, and threatened our very existence. Many critics joined the cry against our schools although they had different motives. In the comfort of their high talents they were against any kindness shown to the less highly endowed. Such critics are those who demand higher standards without offering any concrete proposals how the job is to be carried out in practice within a traditionally democratic society.

The claim that the launching of the Sputniks was due to the high level of Soviet education is on the same low level of logic as the assertion that the V-2 rocket, the magnetic mine, the Snorkel submarine, the jet plane, these and other inventions of the Nazi war machine, were indicative of the marvelous educational system brought into being by Hitler's philosophy of racism. The

V-2 rocket, one of the great inventive achievements of history, was primarily a product of the Nazi philosophy of war and conquest. Similarly, the Sputnik was the outcome of the communist philosophy of class war and conquest, and nothing else. It is the child of the words of the Internationale—"Tis the final conflict, Let each stand in his place, The International Soviet, Will rule the human race. Had Russia been interested in peace and in the UN principles after the war, she would have had no Sputniks, her people would have had ample food, clothing, lodging, and freedom of thought and movement, and the United States would therefore have had no desire to build either atom bombs or missiles.

But the vociferous critics of America and her democratic system of education will have none of this bare-naked truth. They went in the hundreds to Russia, sent there by taxpayers' money or by Foundations of the "robber barons," Ford, Rockefeller, Carnegie, Hill Family etc., and came back to enlighten the American public in their own fashion. Here is a sample picked at random. In the *Atlantic Monthly* of April 1958, Alvin C. Eurich, first president of the State University of New York, in an article "Russia's New Schooling," lauds in foamy words Russia's free education, never mentioning the fees charged in their creches, kindergartens and the upper three high school years, grades 8 to 10. But exaggerating Soviet achievements is not sufficient. The job is half-done unless the U.S. is put in its place. Says Dr. Eurich: "Many of them (i.e. Soviet educators) asked for an exchange of students and faculty. We are the only capitalist nation refusing such cooperation." This charge happens to be false. In April 1949 the U.S. government released a pamphlet entitled *Efforts to Establish Cultural-Scientific Exchange Blocked by USSR* (Pub. 3480, Dep't of State), which is a pitiful record of our pleading, bribing and cajoling the Soviet Government to cooperate in cultural ex-

changes of all kinds, only to be met with the vilest and rudest replies from Stalin. If a court of intellectual justice could convict Dr. Eurich to compulsory reading of this pamphlet, it would be punishment indeed if he has any conscience. Needless to say that all the data about Soviet education his article contains was fed to him by the cultural section of the NKVD and is about as truthful as his statement of our refusing cultural exchanges.

This article is typical of the hundreds of similar reports by American educators. Thus, at about the same time, as high-ranking an American scientist as Dr. Vannevar Bush declared on a national TV program that from his experience with Soviet scientists he concluded they enjoyed as much freedom as any of their American counterparts. He never mentioned that his experience was limited, that the change might be superficial or recent, or that in 1954 The Institute for the Study of the USSR issued a publication entitled *Academic Freedom Under the Soviet Regime, A Symposium*, containing papers by about thirty outstanding "refugee scholars and scientists who have escaped from the USSR" and who tell of scientists who were exiled, tortured and killed under Stalin, in every field, in every specialty. Nor did Dr. Bush give the slightest hint that he was aware of the way planning, staffing and research are predetermined in the scientific sector of the Soviet plans, and that what is seen on the surface has only a faint relation to the doings behind the stage. Nor did he seem to be aware of the two awful purges endured in tears and blood by the Academy, with minor ones in between, as related in Vucinich's *The Soviet Academy of Sciences*, or even the simple story of the *Death of a Science in Russia*, by Conway Zirkle, the persecution of physicists for mere interest in wave mechanics and relativity, or the exile of hundreds of psychoanalysts.

The summer of 1958 saw dozens of faculty

delegations go to Russia. On their return they deployed over the American public in their respective neighborhoods and spoke of teachers' salaries, training, class size, colored chalks, the flowers they received from children who had never previously seen them or known of their arrival, and similar relevant details. Each reporting member of one group cited the old hoax they were fed in Moscow, later uttered with communist solemnity by Khrushchev on his visit here, that before the Revolution Russia had only about 5 per cent literacy in her population. Others put it at 10 per cent. The best data are cited by Timasheff and they prove that European Russia had a literacy rate of over 65 per cent, the cities alone over 75 per cent. The U.S. capitalistic Office of Education states in its publication *Education in the USSR* (1957) that "the situation would seem to support Communist claims of illiteracy in the nation to have been between 60 and 70 per cent," hence a literacy rate of 30 to 40 per cent. William Benton in his *This Is the Challenge*, reports that the Great-Russian Minister of Education cited the literacy figure for that period as 30 per cent while Mr. Palgunov, director of Tass, put it at 65 per cent. The latter figure is apparently correct because, as Timasheff points out, under the latest Tsars Russia was in a frantic race to catch up with the West, much as Japan was in it at the same time. Russia was expanding at a fast pace, which rate it is only now, in 1959, beginning to equal for overall development of her industries, the two wars having cut down the pre-Revolution pace considerably. In agriculture, of course, the production figures of 1913 have not quite been reached but in some industries the rates have increased, as was to be expected.

Most reports sang the praises of Soviet educational achievements and its democratic foundation, and bemoaned the miserable state of the American school system. Yet, as early as April 1958 Khrushchev had al-

ready laid down the new rules to be followed by way of further extending the aristocratic nature of Soviet education modelled after old Russia. As reported by Max Frankel in the *New York Times*, the Soviet premier revealed that in 1957 only 18 per cent of Russia's 10-year Secondary School graduates sought admission to institutions of higher learning, but only 3.5 per cent were accepted by either academic or technical higher institutions. Compare this with the situation in 1913 under the Tsar. Then 8.5 per cent of the elementary school population entered secondary schools, and 22 per cent of the secondary population actually found their way into higher institutions. But what is most significant is Khrushchev's tough warning about the future. He expressed as follows his faith in the glory of education: "More young people should be learning manual trades instead of studying things they never use . . . It is high time, I think, to repattern decisively the system of schooling of our growing generation. All children who go to school must prepare themselves for useful labor. All who scorn labor must be publicly ostracized." Thus, war was declared against the Russian people's traditional love of education. The government will admit to the 8-10 grades of secondary school and to the more advanced institutions of higher learning only those they actually need, and all the others will go to work wherever the state needs them. At the age of 14 or 15 young people that are not fit academically will be put into labor battalions and taught to "respect" labor. Even the chosen ones will be harnessed to factory work during vacation time or will toil half time all along, so as to learn the beauty and nobility of work. Not a word of this anti-intellectual move, put into law in 1958, was mentioned by any of the American government or university experts on education sent at public or private expense to the USSR.

The new reforms in Soviet education seem to indicate that the Soviets are out to

destroy the traditional love of education in Russia in the same way as they destroyed the love of pure science within the Academy. Dr. Vannevar Bush's statement that Soviet scientists are fully as free as American, meaning they can pursue whatever line of research they please, is contrary to every element of Marxist-Leninist thought, and to the actual facts as testified by the plain program of the Academy, or the statements of Russian refugee scientists. It is not an accident that with all the accuracy of the Russian ICBM, the big thrust of the Sputniks, and the indubitable progress Soviet technology has won in the field of space, the three purely scientific attainments of space research so far, namely the high mass and energy particles of cosmic rays, and the Van Allen belts, were American discoveries. In actuality the Russians have so far contributed not one theoretical or non-pragmatic discovery in that sector.

By way of conclusion we might assert that any democratically based educational system faces serious problems and can be greatly improved upon. Democracy brings in its track a lowering of standards, and when prosperity is added to it, the child is deprived of a single-minded will to study because of many freedoms and distractions. Soviet success in the realm of space is due to Russian respect for science, Soviet determination to conquer the world for its communist philosophy, the government's full control over its own manpower, full freedom in secret budgetary allotment, knowledge of all advances in the democratic world with the utmost secrecy in its own actions, and its ability to give special favors or mete out severe punishment for failure by high and low to live up to demanded norms. Soviet success in missiles has no relation whatever to the serious problems which confront every democracy in the field

of education and demand much thought and reform.

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JAMES ARTHUR KEECH

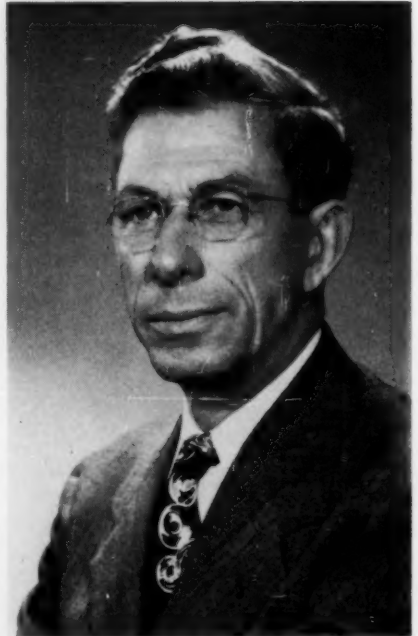
CLARENCE M. PRUITT

It is with deep regret that we report the passing of Professor James Arthur Keech on June 29, 1958 from a coronary thrombosis. He had retired less than a month previously from a teaching career of forty-five years, the last twenty of which had been at Castleton Teachers College, Castleton, Vermont.

Professor Keech was born July 28, 1892 in Rutland, Vermont, the son of Ephraim and Alice Keech. His grade and high school education was received in the Burlington, Vermont schools. He received a B.S. degree from the University of Vermont in 1918 and an M.A. degree from Columbia University in 1924.

His teaching career began as science teacher (1916) and principal (1918) in the Junior High School at Lowell, Vermont. He then taught science in the high schools at Bristol, Connecticut (1919-22) and Yonkers, New York (1923-24). His first college teaching was at the North Carolina State Teachers College, Greenville, North Carolina, 1925-26. During the years 1926-1930 he served as principal of the North Carolina High School. Returning to New England, he taught at the Keene Teachers College, Keene, Vermont, 1931-1937. In the autumn of 1937 he became professor of science at Castleton Teachers College, Castleton, Vermont. He remained at Castleton until his retirement in June, 1958.

Professor Keech married Elsie Ruth Parker April 20, 1919 at Lowell, Vermont. They had four children: James Arthur Keech, Jr. (deceased); Mrs. Warren L. Donnelly (Ferol) Springfield, Massachusetts; Daniel Parker Keech, Greenfield, Massachusetts; and William Legh Keech, Castleton, Vermont. Surviving are also four granddaughters and a grandson. Professor Keech was a member of the Castleton Federated Church.



When legislation required that alcohol education be included in the teachers college curriculum, Professor Keech went as Castleton's representative to the Yale University Alcohol Education Workshop. The program on alcohol education he instituted at Castleton was considered so successful that he was asked to help to set up workshops throughout the state.

Keenly interested in civic affairs, Professor Keech was Secretary-Treasurer of the McConnell Rest Home, Inc.; Deacon of the Federated Church; Past Master of the Lee Lodge Number 30 F and AM; served as Grand Juror and was active in the Vermont State Employees Association and the Vermont Education Association. Membership in educational organizations included the National Association for Research in Science Teaching, the American Association for the Advancement of Science, the National Science Teachers Association,

and the Council for Elementary Science International. We know that Professor Keech valued most highly his membership in the National Association for Research in Science Teaching. Our personal acquaintance with Professor Keech was quite brief but we do recall his great enthusiasm for NARST and for science teaching. As Secretary-Treasurer we always deeply appreciated his deep loyalty to NARST. There was never any concern about his withdrawing membership. On behalf of NARST we extend to Mrs. Keech our heartfelt sympathy on the passing of her noted husband. Mrs. Keech will continue to reside in her Castleton home.

The following citation was read at the Castleton Teachers college Commencement Exercises June 8, 1958:

MR. JAMES A. KEECH has been a member of

the Castleton Teachers College faculty since 1937. This week he will retire after 21 years of faithful and capable service to this institution. In his years at Castleton, Mr. Keech has assisted at many points with the planning and development of our entire natural science division. The major development in this area was the design and equipment of our new Science Building. As a pioneer in the development of an alcohol education program for the State, Mr. Keech worked at the Yale School of Alcohol Studies and had the distinction of establishing the first and most comprehensive undergraduate teachers college course in alcohol education. He has worked effectively and tirelessly with a variety of student clubs and important faculty committees. As a trustee of several educational and civic foundations and as an officer of the municipal government, Mr. Keech has made a significant contribution to the life of the community.

We deeply regret his present illness, hope for his speedy recovery, and assure him of our unqualified appreciation for his many years of outstanding service.

RICHARD J. DUNDAS
President

DEVELOPING A SCRAMBLED BOOK AND MEASURING ITS EFFECTIVENESS AS AN AID TO LEARNING NATURAL SCIENCE *

CHESTER A. LAWSON, MARY ALICE BURMESTER, AND CLARENCE H. NELSON
Michigan State University, East Lansing, Michigan

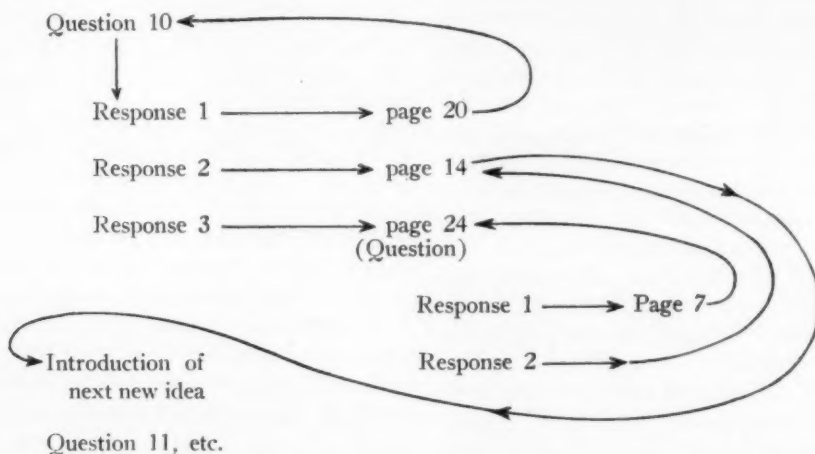
EVER since the inception of the general education course in natural science at Michigan State the faculty has been constantly alert to the development of new methods of teaching for the attainment of the course objectives. Inasmuch as one of the primary objectives of the course is to aid the student in developing his ability to think logically and independently, the use of a "scrambled book" as a teaching device seemed particularly appropriate. The scrambled book requires that the student learn new ideas and that he use these ideas in test situations, frequently involving deduction. The scrambled book is a vehicle that demands rigorous and careful thought on the part of the student; moreover, it immediately checks and corrects him if he makes an error.

* Contribution No. 149 from the Department of Natural Science.

The experimental scrambled book used in a few sections of the course in natural science at Michigan State replaced one week of the introductory material on genetics. We began construction of this scrambled book by rewriting a laboratory study which was of the straight question-and-answer type. In the construction of the scrambled book these questions were used and the correct responses plus several incorrect responses were recorded in multiple-choice fashion. Foils were chosen on the basis of past experience in teaching this study. In programming a scrambled book the sequence of questions is extremely important. Each question must lead to the next in small steps. No step in the thought sequence can be omitted unless new textual material is supplied to fill the gap. In writing the scrambled book it was discovered that cer-

tain gaps occurred in the original laboratory study, gaps that had to be filled in with new questions or by new information. Because the questions were new no immediate source of reliable erroneous answers was available. In order to obtain plausible erroneous answers to the newly inserted questions these questions were presented to students for free response. Their free response answers provided many usable wrong answers couched in student language.

A student who answers all questions correctly proceeds from one question to the next. In the scrambled book, however, this progression from question to question does not follow any particular page sequence. The student who selects an erroneous response is usually directed to a page which corrects the error by explaining the reason for the error. The student is then directed to return to the question and select another answer. Usually, as previously mentioned, the error is corrected directly. In some instances, however, an erroneous response may be followed by another question, or by a series of questions which eventually lead the student into recognizing his own error. For example:



The scrambled book technique has several advantages:

1. The student can work at his own rate rather independently of the teacher.
2. Errors are immediately corrected.
3. It lends itself to a variety of situations. Textual material can be introduced at the exact point where it is meaningful. Students can be directed to make observations of demonstrations at the exact point where the data are required, or they can be directed to carry out experiments to obtain necessary data.

Many problems are encountered, however, in the construction of such an automated teaching device. Even the preparation of a small segment of work in scrambled book form consumes hundreds of hours of time. Certain of the problems are concerned with writing or programming the material, other problems are associated with "scrambling" the material after it is written.

WRITING AND PROGRAMMING PROBLEMS

1. The first problem has already been alluded to. The material must be very carefully organized, so that one idea leads by small steps to the next.
2. One must recognize the kinds of errors students make, the frequency of the types of errors, the reasons for the errors and the techniques of forcing students to correct errors.

3. A third problem is a technical one. Some method must be devised for keeping

the pages to which the student is directed, if he chooses the correct response, separate from the pages which contain explanations of erroneous responses. The method we evolved to handle this difficulty was to use white paper for the normal sequence of questions and yellow paper for explanation of erroneous responses. However, even this technique proved inadequate for the "question-within-question" sequences. Here other colors of paper helped to keep the authors from becoming hopelessly lost in their own maze.

These three problems are concerned with preparation of material and have only indirect relationship to the final product.

"SCRAMBLING" PROBLEMS

After the material was written each question and each explanation of an erroneous choice was put on a separate page. Two copies of these materials were prepared. One, the master copy, was left in normal sequence. The first question, which followed introductory textual material, was given. This was followed by the explanations of erroneous foils, then several questions followed. These page numbers were then entered after the choices. For example,

- Question: — — — —
1. — — — — page 2
2. — — — — page 5 (correct response)
3. — — — — page 3
4. — — — — page 4

This procedure was followed for the entire sequence of questions. Each question and each explanation of an erroneous answer appeared on a page by itself. The pages were then scrambled, each page number changed and each reference to page number was changed. This aspect of the job presented many problems because great care had to be exercised to prevent error. In addition this aspect was both time consuming and dull! When the book was completed it became evident that its bulk would prohibit extensive use of scrambled books

in the course if this method of assembling were to be used. We therefore decided to include more than one question and more than one explanation on each page. A single page, for example, would be numbered 6A, 6B, 6C, 6D, 6E. This revision introduced new problems. We had to be careful not to put a question and its answers on the same page, and we had to be sure that no two answers to the same question appeared on the same page. However, in spite of all the problems that we encountered we found the preparation of the material to be a challenging experience.

EXCERPTS FROM THE SCRAMBLED BOOK INTRODUCTORY UNIT ON HEREDITY

While it is not feasible to reproduce the entire scrambled book unit, excerpts to illustrate certain of its aspects will make more clear some of the points discussed in the foregoing paragraphs. The unit on heredity was developed in three sections. Following are some introductory paragraphs from Section One, followed by the first two questions and commentary to each of the possible responses, here drawn together from the various pages on which these occur. Then to illustrate how a page of scrambled commentary would appear, such a page from this unit is presented.

SECTION I

Problem: To invent a theory which will explain why albinism occurs with greater frequency in Family A than in Family B, and how it is inherited.

It should be apparent to you that all individuals comprising any given population are not identical. They are all very similar in many ways, and they bear more resemblance to each other than any of them would to an organism outside this population. However, individuals within a population differ and by studying the following data taken from a human population, an attempt will be made to uncover some of the facts

regarding the differences of variability within a population.

Compare the two family histories illustrated in Fig. 1. The squares are used to designate males and the circles, females. Horizontal lines connecting a square and a circle indicate a marriage. The vertical line leading downward from a horizontal line leads to another horizontal line from which others lead to individual offspring. The Roman numerals indicate the generation. Note that albinism which is indicated by the solid figures appears in one family history and not in the other. An albino is an organism having a deficiency of pigment in the skin, hair, and eyes. Compare the frequency of albinism in Family A with that in Family B and also compare the frequency of albinism in Family A with its frequency in the population as a whole.

The frequency of albinism in the human population as a whole is one in 200,000.

unreasonable to assume that the environment was the same for both. If, then, the environment is not responsible for the difference between the two families, we shall assume that heredity is responsible.

The pedigree in Figure 2 is a part of the history of Family A. Study this pedigree and answer the following questions.

Albinism "skipped a generation," that is, it was present in the first generation, not present in the second generation and present again in the third generation (the grandchildren). It appears that the grandchildren inherited this characteristic from the grandparents. An initial problem is to postulate how albinism could be transmitted from grandparents to grandchildren without appearing in the parents. To solve this problem it is necessary to begin to think about the reproductive process that was involved in producing the family line. Generation I, produced the individuals of Gen-

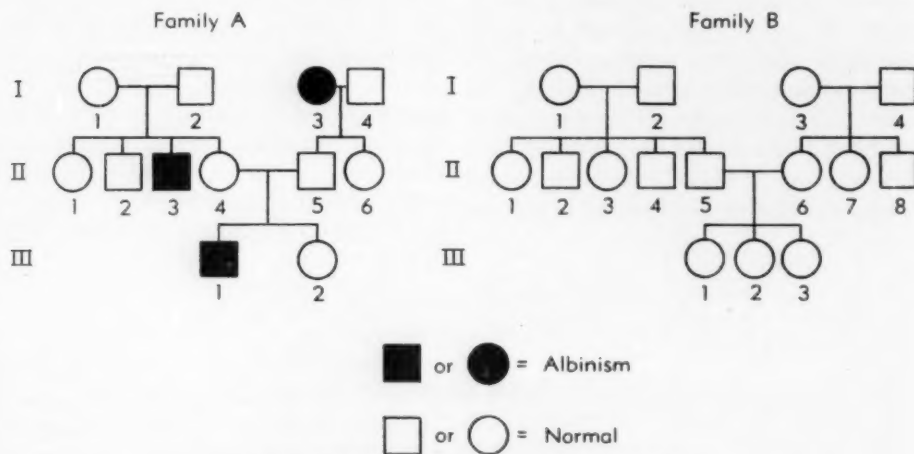


FIG. 1. Pedigree Charts of Families A and B

Thus Family A differs from Family B and also from the population as a whole. Our problem is to devise an explanation that will account for this difference and which will also account for the presence of albinism in Family A and which will explain the "skipping of a generation." Since Families A and B lived in the same locality, it is not

eration II and they in turn produced Generation III. Answer the following concerning sexual reproduction.

Question 1. What is the cellular beginning of a new individual produced by sexual reproduction?

1. Zygote page 4B
2. Gamete page 5A
3. Embryo page 6B
4. Fetus page 3D

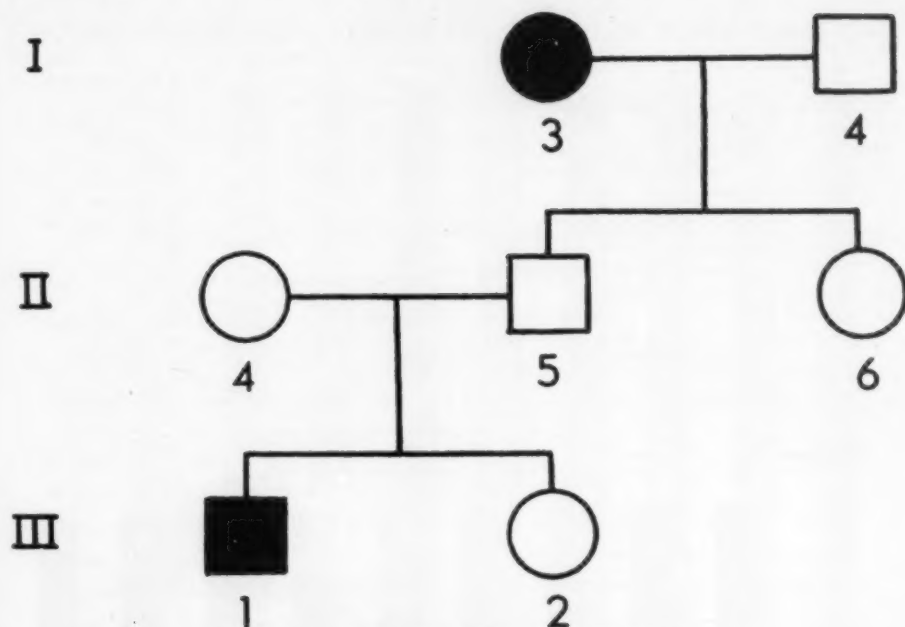


FIG. 2. A Portion of the Pedigree Chart of Family A

You are correct. What contribution does each parent make to produce this cell? 4B

1. Gamete page 5E
2. Egg page 7D
3. Sperm page 16F

A gamete is a single sex cell. Sperm cells and egg cells are gametes. These unite to form a cell which is the beginning of the new individual. What is the name of the structure produced by the union of egg and sperm? Go back to page 2 and try again. 5A

You are slightly in error. An embryo is an organism in the early stages of development but it is later than the one-celled stage. What is the name of the one-celled stage of the new individual? Go back to page 2 and choose another answer. 6B

You are way off. A fetus which has all parts of the individual formed is a late stage in the development. Try again. Turn back to page 2. 3D

From the above commentary, drawn together from four different pages, it should be apparent that the first of the four possible choices was the correct answer to the first question. This, in turn, presents another question with three choices which lead to the following commentary on the possible answers.

OK proceed. Would the four-celled stage of embryonic development of any individual have hair, skin, and eyes through which normal pigmentation or albinism could be expressed? 5E

1. Yes page 6C
2. No page 7C

Your answer is incomplete. The answer you gave is a sex cell produced by one sex. What is the general term for sex cell? Go back to page 4B. 7D

Your answer is incomplete. The answer you gave is a sex cell produced by one sex. What is the general term for sex cell? Go back to page 4B. 16F

It will be noted that the commentary is the same for answer 2 and answer 3. This is justifiable because both of these answers are incomplete for the same general reason.

Now there will follow one complete page of commentary to five different questions. This is the sequence in which the commentary appears on one page of the scrambled book, and this example illustrates the points previously discussed (1) that a question and its answers must not appear on the same page, and (2) that no two answers

Michigan State University—Scrambled Book Answer Page—Natural Science 181

	1	2	3	4	5	6	7	8	9
1	4B								
2	16C								
3		9F							
4		3A							
5		11C							
6		3C							
7	7A								
8	8E								
9	13D								
10				9B					
11	8B								
12		7C							
13	3E	4D	4D						
14			5C						
15							10B		
16				5D					
17	15E	12A	9D	11A	8D				
18					6F				
19				14D					
20		17C							
21		11B							
22	10E	15B	15B	7F	15B	17D	15B	12D	14A
23		10F							
24			16B						
25	14C								
26				15C					
27	17E								

until hair, skin, and eyes are formed. Now proceed to the next question. If anything is passed from the bodies of the parents to the body of the child, what must carry this "thing" from parents to the child?

1. Zygote
2. One of the gametes
3. Egg
4. Sperm

One shortcoming of the first edition of the scrambled book, pointed out by the students after they had used it, was the lack of a record of the sequence of answers they

had selected. This tended to make subsequent review of the unit a bit cumbersome. To overcome this disadvantage a special answer sheet was developed. On this answer sheet the symbols designating possible answers for each question appear in columns. But to encourage the student to consider only one possible answer at a time and to preserve a permanent record of his pattern of responses, the columns of answers have been overlaid with opaque gray bands which can easily be erased.

The student is directed to select an answer to the first question, then erase the space on the answer sheet which corresponds to this selection. A page and paragraph designation will appear after the erasure of one answer space has been completed. The student then turns to the paragraph indicated to find out whether the answer is correct or not. If it is correct he will encircle the symbol on the answer sheet and proceed to the next step. If it is incorrect he will be directed to come back to the question and make another choice of answer. When he succeeds in locating the correct answer he will encircle its symbol designation on the answer sheet. The completed answer sheet will show the sequence of encircled right answers. It will also indicate to the student which questions gave him most difficulty and therefore would warrant most attention in reviewing the unit.

EFFECTIVENESS OF THE SCRAMBLED BOOK AS AN AID TO LEARNING

The scrambled book was developed as a possible means of handling more students per staff member by placing greater responsibility for their own learning upon the students themselves. To be acceptable for this purpose the scrambled book would have to meet three criteria:

(1) It should be almost completely self-administering, thereby not increasing the work-load of the individual staff member even if more students were assigned to him.

(2) It must not result in a deterioration of quality of learning on the part of the student.

(3) It must be regarded by a majority of both the students and staff members as a genuinely useful and stimulating aid to learning and not as a mere novelty.

To determine whether these criteria could be met, the scrambled book was given a rigorous tryout in the 1960 spring term sections of Natural Science 181. Of a total

of ten sections, one-half used the scrambled book while the other half used the chapters in the regular course manual for the introductory unit on heredity. After all students in these sections had completed that unit, two measures of effectiveness were sought. The first of these would attempt to discover any discernible difference in the level of learning achievement of the two groups. The second would attempt to assess the degree of student acceptance or rejection of the scrambled book as a self-teaching device.

To determine how well the students understood what they had covered in this unit and if there was any marked difference between the group that had used the scrambled book and the group that had not, all the students were given the same 30-item objective test including reasoning, analysis, interpretation and application of what had been learned to new situations. The means of the scores and the standard deviations were determined for each group. T-test results indicate that the difference in performance was significant beyond the 1 per cent level of confidence in favor of the sections that had used the scrambled book. The data upon which the foregoing conclusion is based are presented as follows:

	Experimental Group (Used Scrambled Book)	Control Group (Used Regular Manual)
Number of students	144	131
Mean of scores	19.75	17.93
Standard deviation	4.87	4.63
T-test of significance =	3.17	

From the table of t-values this figure gives a significant difference well beyond the 1% level of confidence (the t-value for 1% level being 2.57 for this data.)

According to the above data there is less than one chance in a hundred that the difference in the two means of scores could have been due to chance alone. Since the major variable operating here was the use of the scrambled book, it is likely that the difference in mean scores for the two groups is largely attributable to this variable. It

would appear, therefore, that rather than deteriorating, the quality of learning had been markedly enhanced by the use of the scrambled book.

In addition to comparing the test performance of the experimental and control groups, we were also interested in ascertaining to what extent the students accepted or rejected the scrambled book as a self-teaching device. Accordingly a questionnaire was prepared and given to those five sections that had used the scrambled book. A perusal of the questions and response patterns will reveal that on the whole those who accepted the scrambled book and found it stimulating far outnumbered those who rejected or spoke disparagingly of it. Those who found the scrambled book stimulating tended as a group to phrase their appraisals in better language and to make their evaluation largely in relation to the question of facilitation of learning. Those who made adverse criticisms tended to dwell on such matters as personal inconvenience or frustration while using the device rather than on end results achieved. This latter category of students found little or no stimulus in working out solutions to the exercises themselves. They were more interested in the answers *per se* than in the mental stim-

ulation to be derived from the learning process. They asked for a summary sheet which could become a shortcut to the answers.

Judging from their responses most of the students are not yet ready to dispense with the instructor. Some of them express concern lest the instructor become farther removed from them personally due to increased class size. Most of the students tend to imply that their sense of security would be enhanced if they knew that the instructor was readily available to help them when they encounter any difficulty in their work. But a goodly number of students felt a sense of pride in being self-reliant and being able to teach themselves.

A summary of student responses to the questionnaire follows. Each question was structured but also allowed for an additional free response type of answer. These latter types of answers have been abbreviated somewhat and included as response number six for each question. Question number eleven was completely unstructured and a representative list of responses is presented in each of the two columns, one listing the reasons why the individuals **LIKED** the scrambled book and the other reasons why they **DISLIKED** it.

STUDENTS' REACTION TO THE SCRAMBLED BOOK

1. As to its effect on learning factual materials, the scrambled book is

- 20 1. not very helpful.
- 29 2. interesting but time consuming.
- 46 3. a better device than the manual.
- 27 4. extremely helpful and worthwhile.
- 8 5. I have no opinion on this point.
- 12 6. (Good with manual, helpful but more time consuming than instructor and manual method; distracting; more like a supplement)

2. As to its effectiveness in learning how to reason through a problem situation, the scrambled book is

- 5 1. more of a hindrance than a help.
- 25 2. somewhat helpful, but on the whole more bothersome than useful.
- 56 3. helpful because it leads you to the answer.
- 35 4. not only helpful, but stimulating as well.
- 4 5. I have no opinion on this point.
- 8 6. (Helpful in understanding of the problem; You learn why an answer is wrong; Better than book; More interesting than book)

3. The scrambled book makes review

- 8 1. utterly maddening.
- 47 2. frustrating and time consuming.
- 24 3. interesting but only moderately worthwhile.

- 37 4. interesting and rewarding.
 3 5. I have no opinion on this point.
 21 6. (Easy; Worthwhile; Difficult if distracted at all; Too easy to lose your place; Time consuming; There is so much wasted (sic) time that I don't even want to go back over it.)
4. Skipping around in the scrambled book is
- 11 1. frustrating.
 53 2. distracting.
 9 3. fun and exciting but not very profitable.
 49 4. a stimulating way to learn.
 7 5. I have no opinion on this point.
 12 6. (Frustrating but worthwhile; Stinks; Not effective unless used in sequence; Time consuming; Helps because you think about answer and can't just look at it; Serves as a stimulus.)
5. "The scrambled book corrects you if you make a mistake, and you find out why you are wrong." The foregoing statement is
- 14 1. false and irrelevant to an appraisal of the scrambled book method of learning.
 16 2. false, but if it were true would have some merit.
 25 3. true, but of doubtful value.
 72 4. true and a valuable feature of this learning device.
 7 5. I have no opinion on this point.
 9 6. (By pointing out your errors at the time you make them it is profitable; It rules out any real tough (sic) on the part of the students; You can make a mistake, but it helps to correct with a logical answer; So what!)
6. "The scrambled book enables the student to carry on learning independently, without constant reliance on the Instructor for help." The foregoing is
- 4 1. false and irrelevant.
 10 2. false, but if it were true might have some merit.
 31 3. true, but of doubtful value, because it is better to have continuous assistance from the Instructor.
 74 4. true and a very worthwhile aspect of this device.
 7 5. I have no opinion on this point.
 19 6. (It has opened up a new field of interest that I was sure I would dislike; True, but Instructor also helpful for explanations; Instructor is more informed and gives better answers; Once fouled up in learning from scrambled book one is not any better off than using manual; You also need some advice from Instructor; Some things the Instructor explains better; Student would have difficulty covering the specified materials in the allotted (sic) time for the term.)
7. "If the scrambled book were to be used throughout the term with every unit studied during the term, it would be possible for one instructor to teach more students by having larger sections and letting the students themselves assume a greater responsibility for their own learning." My reaction to the foregoing statement is that this
- 24 1. should never be allowed to happen, because in smaller classes a student can get more help from the instructor.
 54 2. might conceivably come to pass, but it would not be altogether desirable.
 0 3. would be a good thing because it would save taxpayers' money.
 44 4. would be desirable because it would train students to become more self-reliant.
 6 5. I have no opinion on this point.
 21 6. (If the whole scrambled book scheme (sic) is to find out if it is possible to cram more students into N.S. sections #1 must be chosen; Hard to get special help; With scrambled book there would be less need for special help; S.B. would not replace instructor but it reduces need for instruction; I see no reason why this system could not be established; S.B. is too confusing on some points—student still needs explanations from the teacher; Too much time is spent reading it; Less would be truly learned; Wouldn't need the teacher.)
8. The best way to learn science is to
- 2 1. go and see the instructor frequently so as to get some idea what is likely to be emphasized on the quizzes and tests.
 11 2. listen attentively in class, take notes on everything that is said, then memorize these notes for the examinations.

- 44 3. work out the lab. studies cooperatively with other students so as to get the benefit of each others' thinking.
- 75 4. ascertain quickly what the problem under consideration involves, then think through to the solution as efficiently as possible without outside help unless absolutely necessary.
- 5 5. I have no opinion on this point.
- 23 6. (Discussing a problem has many good merdits (sic); At least working with other students is better than one instructor for 30 students in a lab; Take notes and work out lab as well as seeing instructor for help; study everything; Memorize terms and put them together; Understand the work and if you don't see the Instructor.)

9. How should the scrambled book be used in Natural Science?

- 16 1. Regularly instead of the manual.
- 75 2. Regularly but as a supplement to the manual.
- 26 3. Occasionally for variety.
- 13 4. It should be discontinued.
- 7 5. I have no opinion on this point.
- 10 6. (This could, however, have a frustrating effect on people; Possibly some revision will be desirable for certain areas; It should be burned!)

10. If the scrambled book is used instead of the manual for some, or even all, of the lab. studies and readings, how should the ideas in the scrambled book exercises be reviewed and interrelated?

- 32 1. By the instructor in lecture.
- 31 2. By doing supplemental reading which explains further what is involved in the exercises.
- 79 3. By students and instructor cooperatively during the recitation period.
- 4 4. This is not necessary if the students have worked through the exercises thoroughly.
- 9 5. I have no opinion on this point.
- 10 6. (Have review questions at the end (Sec. III) and gone over by instructor; A summary at end of booklet would be extremely helpful; A review sheet would help greatly; Not a bad plan substituting the scrambled book for the lab. studies in the manual.)

11. I like the scrambled book because—

if you did have the wrong answer it explained why you were wrong.

it provides a different and stimulating new way to learn, but it should not be used exclusively.

I had all the information at my fingertips, not somewhere piled in my notes. It also gave me the satisfaction of teaching myself.

I had a chance to have questions asked continuously like the ones on our tests.

it gave me a sense of discovery.

it makes a good supplement rather than a replacement for the lab book and instructor.

I got enjoyment out of this that I don't get out of the manual.

you benefit by your error right away instead of finding out on a test.

it is actually a game with rewards and punishments!

it can be done anywhere and without help.

it helps one to become more self-reliant.

you do not have to wait for the instructor to check each answer before you can go on.

it makes the student think the problem through instead of memorizing facts.

I do *not* like the scrambled book because—
of the jumping around.

too much time is spent in reading it.

reviewing the subject is difficult.

the dept. is sacrificing understanding for the sake of larger classes.

one has the tendency to go through the steps mechanically.

it is apt to lead to larger classes and less help from the Instructor.

you can learn better if the facts are clearly stated in the manual.

a student fresh out of high school does not have the initiative to learn all of the exercises on his own.

it takes too much time.

it creates a greater gap between teacher and student.

it seemed to be a silly game.

it has too many sticking brakes.

it required too much page turning.

it takes too long to come to the point.

These are just a few representative free response statements. Actually the **LIKES** tended to outnumber the **DISLIKES** by about 4 to 1.

STAFF COMMENTS ON THE USE OF THE
SCRAMBLED BOOK

"Such industry on the part of the students (when using the scrambled book)—it is amazing!

The only sound you could hear was the turning of pages."

"With this (scrambled book) I could teach 1000 students! However, review may present a problem."

"When I walked out of the room the students (busily at work on the scrambled book exercises) were hardly aware that I had gone. When I returned they were still working just as diligently as they were before I left."

SUMMARY

A method of constructing a scrambled book has been described. Problems of writing and programming course materials have been dealt with followed by a discussion of problems related to the scrambling process.

Examples of format have been provided which embody some of the principles of construction previously discussed. The special answer sheet developed expressly for the scrambled book has been described and illustrated. Finally, the results obtained with the scrambled book and a sampling of student and staff reaction to it have been presented. While this is not a definitive study it does provide a few insights which may be useful as a basis for developing a more refined experimental design to be used in subsequent studies related to this subject.

DESIGN OF OBJECTIVE TEST ITEMS TO EVALUATE THINKING ABILITY IN SCIENCE *

FLOYD MONAGHAN

Michigan State University, East Lansing, Michigan

It is frequently asserted that objective type tests are fine for sampling factual knowledge but are of little worth if one wishes to examine a student's ability to think. It is granted that the assertion is true of many objective type tests. It is here argued that this need not be the case, that objective type test can be designed that will permit evaluation of student's thought processes. Several sample items will be offered below in illustration of some things that have been tried by the author. The method of analysis used in developing the questions will be given. The items will be given first in the more usual form of such material and then in a more developed form. The examples chosen are from the areas of Mathematics and Physical Science. Similar items have been developed in Geology and in the Biological Sciences. The whole series has been prepared as part of the examination program of the Department of Natural Science in the Basic College at Michigan

* Contribution No. 137 from the Department of Natural Science.

State University and in co-operation with some members of the Evaluation Services Staff.

Consider first of all the area of Mathematics. Items in this area usually consist of stating the problem in some form, with the responses made up of a correct answer plus a number of incorrect answers, usually three or four, based on common errors made by students. As an alternative, a student may be given a problem and asked to select the correct formula from a set listed as foils or responses.

Let us assume a topic in arithmetic progressions has been taught leading to the development of the general formula for the sum of an arithmetic progression and that arithmetic and geometric progressions have been illustrated and compared. Let us further assume that the general formula for the sum of the geometric progression has not been developed.

The general formula for the sum of an arithmetic progression is $S = 1/2 n (L + a)$ where S = sum of the progression.

n = number of terms in the progression
 L = last term
 a = first term

The usual item in this area might take the following form:

Ex. 1. The sum of an arithmetic series beginning with 1 and containing the first forty consecutive terms (i.e. $1 + 2 + 3 + 4 + \dots + 40$) is _____

- (1) 780 (2) 800 (3) 820
 (4) 1640 (5) none of these

Response five protects the examiner in case he has made an error and failed to include the correct response. The others are derived thus

- (1) by subtracting a instead of adding it thus: $1/2 \times 40 (40-1) = 20 \times 39$
 (2) by failing to add a thus: $1/2 \times 40 \times 40 = 20 \times 40$
 (3) the correct response: $1/2 \times 40 \times (40 + 1) = 20 \times 41$
 (4) by failing to multiply by $1/2$ thus: $40 \times (40 + 1) = 40 \times 41$

If the student marks 1, 2, or 4, (all wrong) we may learn something about which of the common errors he has made. If he marks 5, this may mean he has made some error we have not anticipated. If he leaves the item unscored this may be because he has failed to recall the formula, or having recalled it, has forgotten what the individual terms mean. If he marks 3 this may mean that he knows what he is doing or it may be due to chance alone. The correct response if given, also does not tell us whether he can recognize an arithmetic progression as distinguished from a geometric progression or a mere series of numbers that does not belong to either classification.

It would be much more informative in such a situation if we knew whether the student could recognize the class to which a given sequence of numbers belonged; could state the criterion of classification; whether having placed the series he could select the correct relationship from a variety offered; whether having selected the relationship he could recognize the nature of the information given and/or deducible; whether he could make proper numerical substitutions for the variable; and finally

whether he could calculate the correct numerical answer.

This latter, more developed approach might take the following form:

Ex. 2. The following sequence of numbers is the basis for questions 1 through 9. Examine it carefully and then proceed. Sequence $1 + 2 + 3 + 4 + 5 + \dots + 40$. The sequence consist of all the natural numbers from 1 through 40.

1. To what class of progressions does this sequence belong?
 (1) arithmetic
 (2) trigonometric
 (3) geometric

- (4) logarithmic
 (5) none of these
 2. The distinguishing characteristic of these of progressions is
 * (1) constant difference between successive terms.
 (2) constant ratio between successive terms.
 (3) constant product of successive terms.
 (4) constant quotient between successive terms.
 (5) constant sum between successive terms.
 Note: One of the responses may be replaced by "none of these."
 3. On the basis of your responses to 1 and 2, the correct formula for finding the sum of the progression at any point is
 (1) $a + (n - L) d$
 (2) $rL + a/r - L$
 * (3) $1/2n (L + a)$
 (4) ar^{n-L}

Respond to items 4 through 8 by matching each symbol with the appropriate response from the key.

- KEY: (1) is the number of terms in the progression
 (2) is the ratio of successive pairs of terms
 (3) is the difference between successive pairs of terms
 (4) is the last term
 (5) is the first term

4. n
 5. d
 6. L

7. r 8. a

9. The correct numerical value for the sum of the progression as stated at the beginning of this series of items—i.e. all the natural numbers 1 through 40 is:

- (1) 780 (2) 800 (3) 820 (4) 1640
(5) none of these

* * * * * * *

If it seems desirable to carry the process one step further, the students may be given a problem such as the following which can be solved readily if the student is able to perceive it as one involving arithmetic progression.

Ex. 3. Suppose you have been hired on a job working 40 hours a week. The pay scale runs thus: 1st hour \$0.10, 2nd hour \$0.20, 3rd hour \$0.30 and so on continuously through the 40th hour. What will be the amount of your pay for the week?

An analytic series of questions similar to that detailed above will give considerable insight not only into the amount and kind of factual knowledge possessed by the student, but also into his ability to do something with that knowledge. Further, the analysis and the test results together may enable the instructor to modify the sequence in teaching the topic in a useful way.

Another question to which we would like an answer in such a subject matter area is, how well does the student comprehend the kind of a pattern of thought involved in developing a formula such as that for the sum of an arithmetic progression? Can he think his way through a new problem of similar type when confronted with some clues? The following sequence was constructed in an attempt to explore this situation where the formula for the sum of an arithmetic progression has been developed, geometric progressions had been defined and illustrated but the general formula for the sum of such progressions had not been developed.

Ex. 4. Consider the following tables where the upper row is a geometric progression, and the lower row indicates the sum of the terms of the progression at each point.

As in your studies of arithmetic progressions L = last term a = first term. We will add r = ratio of any two successive terms.

1	2	4	8	16	32
	3	7	15	31	63

The specific formula for the sum of this progression at any point is $2L - 1$. A second series of this same kind is

2	4	8	16	32
	6	14	30	62

The specific formula for the sum of this progression at any point is $2L - 2$.

1. The specific formula for the sum of the following progression is —

4	8	16	32	64
	12	28	60	124

- (1) $4L - 2$ (2) $4L - 2a$ (3) $2L - 3$
*(4) $2L - 4$ (5) none of these

2. A more general formula including all of the above as specific cases is

- (1) $2a - L$ (2) $L - 2a$ *(3) $2L - a$
(4) $a - 2L$ (5) none of these

3. A still more general form than that in question 2 would be

- (1) $r(L - a)$ (2) $L - ra$ (3) $L - 2r$
*(4) $rL - a$ (5) none of these

4. Consider the following example and select the specific formula for the sum of this progression at any point.

1	3	9	27	81
	4	13	40	121

- (1) $2L - 41$ (2) $L - 40$ *(3) $(3L - 1)/2$
(4) $(2L - 1)/1.33$

5. Consider the following example and select the specific formula for the sum of this progression at any point.

1	4	16	64	256
	5	21	85	341

- (1) $2L - 171$ (2) $2L - 43$ *(3) $(4L - 1)/3$
 (4) $(3L - 2)/4$ (5) none of these

6. On the basis of the foregoing, a more general formula that will include each of the preceding formulas will permit finding the sum of any geometric series is:

- (1) $\frac{rL - ra}{r - 1}$ *(2) $\frac{rL - a}{r - 1}$ (3) $\frac{a - L}{r - 1}$
 (4) $\frac{r(L - a)}{r + 1}$ (5) none of these

* * * * *

Let us consider next a situation where the elements of binary arithmetic have been taught as a means of improving understanding of the basic principles underlying number systems and the way in which rules for notation and computation may be developed. It is desired to find out how well the students have comprehended the pattern of the system. One way to do this is to ask the student to perform some simple calculations in binary numbers; another is to test directly for recall of the rules and principles using standard binary notation. An approach which permits less reliance on rote memory is that shown in the items below where the student not only recalls information but indicates his comprehension or lack of it in attempting to translate his knowledge into new symbols.

Ex. 5. The society for inter galactic exploration reports that there exists on planet X a race of intelligent beings that have hands and arms somewhat like our own except that they have no fingers or thumbs. Lacking our number of digits to count on their number system contains only two symbols. The word they use for the absence of quantity is "nug" which is roughly equivalent to our English word "no". The symbol they use for this is roughly like our n and we will use this as its equivalent. Their word for a unit quantity is "yug" which may be roughly translated as "yes". The meaning is yes, something is there, or is present. For this term we shall use the letter y .

They represent the beginning items of the standard series of collections which is like ours thus:

* ** *** **** *****
 y yn yy ynn yny

Clearly the system is like our familiar binary notation.

1. On this basis, using their symbols, a collection like this in the standard series * * * * * would be represented by the symbols

- (1) nny *(2) yyn (3) yny (4) nyn
 (5) none of these

2. From the above example of collections it appears that they have a basic rule of addition which may be expressed

- (1) $y + y = y$ (2) $y + y = yy$ (3) $y + y = n$
 (4) $y + y = ny$ *(5) $y + y = yn$

3. It also appears that this parallels our binary rule that

- (1) $1 + 1 = 1$ (2) $1 + 1 = 2$ *(3) $1 + 1 = 10$
 (4) $1 + 1 = 01$ (5) $1 + 1 = 1$

4. Another of their fundamental rules must be that

- *(1) $y + n = y$ (2) $y + n = n$ (3) $y + n = ny$
 (4) $y + n = yn$

5. This appears to correspond to our binary rule that

- (1) $1 + 0 = 0$ *(2) $1 + 0 = 1$ (3) $1 + 0 = 10$
 (4) $1 + 0 = 01$

6. If this is true we shall be able to understand their calculations performed on measured quantities of concepts because of the — between their system and our binary system.

- (1) compensation (2) assymetry *(3) analogy
 (4) opposition (5) intersuction

7. It appears that their intelligence is like our own in that they have employed certain fundamental principles in the constructing of their system. These are to be selected from the key and the appropriate responses marked

- (1) a, b, c
 *(2) b, d, g
 (3) c, e, h

(4) b, c, f

(5) a, c, e

KEY: a. inversion

b. non-contradiction

c. infraction

d. position valve in notation

e. retraction

f. uglification

g. one to one correspondence

h. fluxion

* * * * *

Here as in the preceding sets of examples the student's factual knowledge is tested and also his ability to utilize facts and principles in a new situation. Let us now turn to another area, Physics.

Let us assume that a series of topics in mechanics covering free fall, conservation of energy and work-energy relationships has been taught. We wish to examine the student's grasp of distance-velocity-time relationships and other related matters. A problem which might be used in this situation is the following:

Ex. 6. A metal ball having a mass of one pound (1 lb.) is thrown vertically upward with an initial velocity of 96 ft./sec. as it leaves the thrower's hand. How long will it continue to rise?

- (1) 1 sec. (2) 2 sec. *(3) 3 sec.
(4) 4 sec. (5) 6 sec.

Such a treatment fails to exploit the possibilities of the situation and only tells us whether the student is able to get the correct answer. It tells us nothing about the nature or quality of his thought processes nor does it enable us to diagnose his difficulty. What are some of the things we might wish to know in this or similar situations? We might wish to know some or all of the following:

1. How well can the student analyze the problem situation into
 - (a) the thing that he is to find as the answer?
 - (b) relevant and irrelevant components of information given?
2. Can he recognize what fundamental principle (or set of assumptions) is to be applied in a given situation?

3. Can he decide on a relationship linking what is required with what is given?

4. Can he recognize that while some things he may need are missing from the given information, he can deduce them from what is given? Or that he cannot deduce them and no numerical answer may be possible?

5. Can he make proper numerical substitutions in the relationship selected?

6. Given all the foregoing can he calculate correctly and obtain a numerical answer when this is possible?

This analysis suggests the use of a key against which the student evaluates selected elements of the problem. Such a key might take the following form:

- KEY: (1) is the thing to be found as answer to the problem.
(2) is given and is needed to solve the problem.
(3) is given but is not needed to solve the problem.
(4) is needed in order to calculate the answer but is not given although it can be deduced from what is given.
(5) is needed in order to calculate the answer but is not given and cannot be deduced from what is given.
(6) can be calculated but is not the answer.

or an alternative form:

- KEY: (1) to be found (the answer).
(2) needed and given.
(3) needed, not given, but deducible.
(4) needed, not given, not deducible.
(5) not needed, not given, but deducible.
(6) not needed, not given, not deducible.
(7) not needed, but given (irrelevant).

Still another form may be constructed by interchanging given and needed in all except response 3 of the above key.

If the problem is given initially in an essay form with a requirement that the student show all of his work in reaching the answer at least the following three patterns leading to correct results will emerge

Pattern 1. The student reasons thus:

- (a) The ball slows down as it goes up at the same rate it speeds up when it falls back.
- (b) At the top of its flight it stops moving for just an instant.
- (c) If air resistance is not important, it

- should have the same velocity when it returns to my hand as when I threw it.
- (d) What I need to decide is how long it would have to fall from rest to have a velocity of 96 ft./sec.
- (e) I know that in free fall when initial velocity is zero $V_t = at$.
- (f) Here $a = +32$ ft./sec. in free fall and $V_t = 96$ ft./sec.
- (g) Then 96 ft./sec. $= 32$ ft./sec. $\times t$.
- (h) t must be 3 sec. since $3 \times 32 = 96$.

Pattern 2. The student reasons thus:

- (a) As the ball goes up, its velocity decreases each second by just as much as it would increase in each second of free fall, that is by 32 ft./sec. for each second it rises.
- (b) I just keep subtracting 32 ft./sec. from the initial velocity till the last difference is zero or some fraction of 32.
- (c) Then 96 ft./sec. $- 32$ ft./sec. $= 64$ ft./sec.
 64 ft./sec. $- 32$ ft./sec. $= 32$ ft./sec.
 32 ft./sec. $- 32$ ft./sec. $= 0$
- (d) I subtracted 32 three times therefore the ball will continue to rise for 3 seconds.

Pattern 3. The student reasons thus:

- (a) I want to find the time the ball is rising.
- (b) I know the initial velocity is 96 ft./sec.
- (c) The velocity of the ball when it stops rising must be 0 ft./sec.
- (d) The acceleration going up is -32 ft./sec./sec.
- (e) The relationship $V_t = V_i + at$ includes all these as knowns and leaves only time as unknown.
- (f) The time is what I want to find.
- (g) Then 96 ft./sec. $= V_i$ $V_t = 0$ $a = -32$ ft./sec./sec. $t = ?$
- (h) $0 = 96$ ft./sec. $+ (-32$ ft./sec./sec. $\times t$ sec.)
 $0 = 96$ ft./sec. $- 32$ ft./sec./sec. $\times t$ sec.
 -96 ft./sec. $= -32$ ft./sec./sec. $\times t$ sec.
 t sec. $= -96$ ft./sec./to $\div 32$ ft./sec./sec.
 $t = 3$ sec.

Examination of each of these patterns will show that the student

- (a) assumes that the mass of the ball and its material are not relevant to the solution of the problem.
- (b) recognizes that the acceleration of the rising ball is numerically equal to the acceleration of the falling ball but is opposite in sign, though this is not given directly in the problem.
- (c) recognizes that the velocity of the ball at its maximum height is zero although this is not given directly in the problem.

- (d) recognizes that $V_t = V_i + at$ or $V_t = at$ is involved either explicitly or implicitly.

With all of these factors in mind we may proceed to the design of an item series such as that illustrated below.

Ex. 7. Instructions—Read the following statement carefully. Items 1 through 12 relate to this statement.

How long will a metal ball weighing one pound continue to rise if it is thrown upward with a velocity of 96 ft./sec.?

1. Following are some statements relating to this problem. Which of the responses is correct?

- (1) The ball is accelerated -32 ft./sec² as it rises.
- (2) The ball is accelerated $+32$ ft./sec² as it falls.
- (3) At maximum height all of the energy of the ball is potential.
- (4) At maximum height the velocity of the ball is zero.
- *(5) All of the above.

Evaluate each of the following statements 2 through 9 about the problem according to the following key:

- KEY: (1) is the thing to be found as answer to the problem.
- (2) is given and is needed to solve the problem.
- (3) is given but is not needed to solve the problem.
- (4) is not given, is needed, but is deducible.
- (5) is not given, is needed, but is not deducible.
- (6) is not given, is not needed, but is deducible.
- (7) is not given, is not needed and is not deducible.

2. the mass of the ball.
3. the fact that the ball is metal.
4. the time during which the ball is slowing down.
5. the time during which the ball is speeding up.
6. the maximum height to which the ball will rise.
7. the acceleration due to gravity.
8. the total time the ball is in the air.
9. the time during which the ball continues to rise.

10. Which of the following combinations of numbers lists the statements in Ex. 7. Item 1 that provide information not given in the original statement but needed to solve the problem?

(1) 1 and 2 (2) 1 and 3 (3) 1 and 4
(4) 2 and 3 (5) 2 and 4

11. Which of the following relationships is the correct one to be used in solving the problem?

(1) $W = F \times s$ (2) $s = 1/2 at^2$
(3) $V_t = V_i + at$ (4) $s = V_i t + 1/2 at^2$
(5) $KE = \frac{mv^2}{2g}$

12. The correct answer to the problem is

(1) 5 (2) 144 (3) 3 (4) 288 (5) 6

* * * * * *

Let us turn our attention next to another problem from the same general area, mechanics. The usual method again would be to state the problem, give a list of answers as responses and require the student to select the correct answer. The process of analysis leading to a more developed form is quite similar to that of the preceding series and will not be given in such great detail.

Ex. 8. Read the following problem statement carefully. Questions 1 through 10 relate to this problem.

An automobile having a mass of 3200 lb. is moving with a velocity of 30 m.p.h. (44 ft./sec.) along a level concrete road wet with rain. What is the minimum distance (neglecting reaction time) within which the car can be stopped if the stopping force available without skidding the tires is 1600 lbs.?

1. The principle to be applied in the solution of the problem is that:

(1) the work done setting the car in motion is converted to potential energy.
(2) the work done setting the car in motion is converted to kinetic energy.

*(3) the work done stopping the car must be equal to the car's kinetic energy.

103 (4) the work done stopping the car must be equal to the car's potential energy.

Listed below are a number of formulae. On the basis of your conclusion in item one and your knowledge of the meanings of these formulae answer items 2 and 3.

2. If you need only one of the following formulae mark the appropriate response *one* through *four*. If you need two of the formulae mark space five and go on to item 3.

(1) $F \times s$ (2) $m \times s$ (3) $1/2 at^2$
(4) mv^2 (5) need more than one of the above
 $2g$

3. If you need two of the above formulae select the correct response from the list below, one through four. The numbers in the response refer to those in the preceding item. If you have already decided that you need only one formula then mark space 5 in this item and continue with item 4.

(1) 1 and 2 (2) 1 and 3 (3) 1 and 4
(4) 2 and 4 (5) none of these

Evaluate each of the following statements 4 through 9 about the problem according to the following key:

- KEY: (1) is the thing to be found as answer to the problem.
(2) is given and is needed to solve the problem.
(3) is given but is not needed to solve the problem.
(4) is not given, is needed, but is deducible.
(5) is not given, is needed, but is not deducible.
(6) is not given, is not needed, but is deducible.
(7) is not given, is not needed and is not deducible.

NOTE: A shortened form of the key given below may be used if desired.

- KEY: (1) is given and needed to calculate the answer to the problem.
(2) is given but not needed to calculate the answer to the problem.
(3) is the thing that is to be found, (the answer).
(4) is not given but is needed for the solution of the problem.
(5) is not given and is not needed.

4. The fact that the road surface is wet concrete.

5. The mass of the car.

6. The reaction time of the driver.
7. The velocity of the car.
8. The acceleration due to gravity.
9. The stopping distance.
10. The correct answer to the problem is

- (1) 48,400 ft. (2) 121 ft. (3) 60.5 ft.
- (4) 193.6 ft. (5) none of these

* * * * * * *

In conclusion let us examine an item series based on the gas laws. We would like to know whether the student can recognize the variables and also the constants in the problem situation. We would like to know whether he can decide what law applies to the particular case; whether he can recognize how the size of the anticipated answer should compare with the initial volume, temperature, or pressure as the case may be; whether he can select the correct formula and whether he can calculate the correct answer.

Once again our analysis provides the specifications for the item series we need to construct. Again one portion of the series can be based on the seven-point key used before to test recognition of relevance of the information given in the problem situation.

Ex. 9. Instructions: Read the following paragraph carefully. Items 1 through 16 will be based upon it.

Hydrogen gas is pumped into a container at 27° C. until the pressure in the container reaches 1500 lb./in² at which pressure the container is sealed. The container which has a volume of 1 cubic foot is sufficiently rigid so that its volume does not change under the conditions of the experiment. After the container is sealed it is heated to a temperature in excess of 300° Abs. The pressure at this higher temperature will be _____.

1. Select the one response from the following which includes only the variable(s) in the above situation and includes all of them.

- (1) P (2) V (3) T (4) P & V
- *(5) P & T (6) V & T

2. Using the same set of responses as in item one select the one response which includes the factor(s) being held constant.
3. On the basis of your responses to items one and two select from the following list the name of the gas law which applies here.

- (1) Boyles' law (2) Gay-Lussac's law
- (3) Charles' law (4) Avogadro's law
- (5) Graham's law

On the basis of your responses thus far and the statement of the problem evaluate each of the following by selecting the appropriate response from the key.

- KEY: (1) is the thing to be found as answer to the problem.
- (2) is given and is needed to solve the problem.
 - (3) is given but is not needed to solve the problem.
 - (4) is not given, is needed, but is deducible.
 - (5) is not given, is needed, but is not deducible.
 - (6) is not given, is not needed, but is deducible.
 - (7) is not given, is not needed and is not deducible.

4. The kind of gas in the container.
5. t_1
6. P_1
7. The volume of the container.
8. T_1
9. P_2
10. T_2
11. V_2
12. the fact that the volume of the container does not change.
13. On the basis of the information given, which of the following inferences is correct as regards this problem?

- (1) T_2 is greater than T_1 therefore P_2 will be less than P_1 .
- (2) T_2 is greater than T_1 therefore P_2 will be greater than V_1 .
- (3) T_2 is greater than T_1 therefore P_2 will be greater than P_1 .
- (4) T_2 is greater than T_1 therefore P_2 will be the same as P_1 .
- (5) No such inference is possible.

14. On the basis of your inference above

and your evaluation of items (6-12). The correct formula to use for this type of problem is

- | | |
|-------------------------|--|
| (1) $P_1 V_1 = P_2 V_2$ | (4) $P_1 = P_2 \times \frac{T_2}{T_1}$ |
| (2) $P_1 T_1 = P_2 T_2$ | (5) none of these |
| (3) $P_1 T_2 = P_2 T_1$ | |

15. The correct answer to the above problem is

- | | |
|-------------------------------|---------------------------------|
| (1) 2000 lb./in. ² | (4) 14,650 lb./in. ² |
| (2) 1000 lb./in. ² | (5) none of the above |
| (3) 1070 lb./in. ² | |

16. If T_2 were known to be 400° Absolute, which of the above answers would be correct?

In the preceding pages an attempt has been made to indicate some ways in which test items of objective type may be developed that will do more than just sample knowledge of facts. Items of these types

have been used in the author's classes at M.S.U. for several years with considerable satisfaction. Students find that they obtain improved insight into the weaknesses and strengths of their knowledge and abilities. They react favorably to items of this type as allowing them to obtain credit for more of their knowledge than do questions of the one-shot type. They particularly like not losing all credit on a problem because of an error in calculation. As a diagnostic device, this type of item enables the instructor to put his finger quite exactly on the point of weakness in a student's preparation, or on weaknesses in his own teaching of a topic.

No claim is made that the examples offered here are perfect of their kind, only that they are an improvement over less developed forms and that they point a desirable direction for further development.

PROBLEM-SOLVING: A COMPARISON OF THE EXPRESSED ATTITUDES WITH THE CLASSROOM METHODOLOGY OF SCIENCE TEACHERS IN SELECTED HIGH SCHOOLS

THOMAS G. AYLESWORTH

Michigan State University, East Lansing, Michigan

IN summarizing the results and conclusions in the research related to problem-solving, several generalizations seem to be evident that indicate not only the desirability of the direct teaching of the problem-solving method, but also the need for this type of teaching. It has been concluded many times, both descriptively and experimentally, that there is a lack of the direct teaching of the problem-solving method in our schools, that students need practice in problem-solving in order to utilize the method effectively, and that science teachers approve of this method in theory, but not in practice. Thus, it would seem highly desirable that steps be taken to help teachers, and especially science teachers, to relate their theoretical

belief in the problem-solving approach to the practical application of teaching this method directly in the classroom.

The reasons for the importance of giving practice in problem-solving to the students in the classroom were demonstrated experimentally by studies that indicated that a knowledge of facts does not lead necessarily to an application of these facts, there may be little relationship between intelligence and reasoning ability or between age and reasoning ability, and there is no corresponding development in reasoning ability as the student grows older. On the other hand, while factual knowledge may aid in the explanation of phenomena, the ability to

solve problems aids the student in all types of reasoning situations.

There would seem to be little disagreement among the research people in this area of education that practice in solving problems is necessary in the curriculum of the school. Most of them deplore the lack of this type of teaching, and most of them point out or imply that we are cheating school children, and consequently future generations, by not equipping students to solve problems effectively.

After the reasons for the importance of teaching by the problem-solving technique are considered, there arise three questions which should serve as a statement of the problem under consideration:

1. What attitude is expressed by science teachers toward the teaching of problem-solving as a desirable objective of the science course?
2. What methods do science teachers indicate that they use in teaching problem-solving skills?
3. What methods do science teachers actually use in teaching problem-solving skills?

THE QUALITATIVE TECHNIQUES

It was decided that observations of classroom situations in selected high school science classes would be an effective technique to use in evaluating the kinds of direct teaching of the problem-solving procedure that might be found in public schools in Michigan. Arbitrarily, twenty observations were scheduled: twelve biology classes, four chemistry classes, and four physics classes. Equally arbitrarily, three biology classes, one chemistry class, and one physics class were selected in schools of four sizes: schools with enrollment of under five hundred, schools with enrollments of from five hundred to one thousand, schools with enrollments of from one thousand to two thousand, and schools with enrollments of over two thousand.

These schools were selected not only on the basis of size, but also on the basis of geography. It was felt that the best way to ensure cooperation for the study was to

make contact with the schools and teachers involved through a member of the faculty of Michigan State University stationed in the vicinity. This faculty member was, in some cases, a Resident Coordinator of Student Teaching, and, in other cases, the director of a Continuing Education Center. Either responsibility would put the faculty member in a position of being able to judge the teachers of the community concerning their desirability as subjects for the study. These men were asked to select and contact science teachers of average ability who might seem to reflect in their teaching the normal procedures and educational philosophy of the school in which they taught.

Observations were made at twelve different schools: four with enrollments of under five hundred, three with enrollments of between five hundred and one thousand, three with enrollments of between one thousand and two thousand, and two with enrollments of over two thousand. Within each group, no two schools were less than twenty-five miles apart, geographically speaking, but all were within a radius of one hundred miles of the state capital, Lansing. By not observing in a wider range than this, certain problems were avoided, such as differences in regional attitudes toward education in general, differences in courses of study, and differences in salary schedules of teachers.

Inasmuch as the teachers observed were carrying on a discussion session at the time of the observation, mere notetaking of what was said and done was not sufficient. A tape recorder was taken into the classrooms and notes of various observable behavior were integrated into the stenographic transcription of the class discussion. The chief reason for the use of the tape recorder was that most of the lists of problem-solving behaviors concern themselves almost exclusively with behaviors that are orally verbal, including few that are non-verbal in character. Because of this fact, word-for-word transcriptions, with appropriate notations of non-verbal behavior relating to the problem-solving process, seemed to be the

and your evaluation of items (6-12). The correct formula to use for this type of problem is

- (1) $P_1 V_1 = P_2 V_2$ (4) $P_1 = P_2 \times \frac{T_2}{T_1}$
 (2) $P_1 T_1 = P_2 T_2$
 (3) $P_1 T_2 = P_2 T_1$ (5) none of these

15. The correct answer to the above problem is

- (1) 2000 lb./in.² (4) 14,650 lb./in.²
 (2) 1000 lb./in.² (5) none of the above
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16. If T_2 were known to be 400° Absolute, which of the above answers would be correct?

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IN summarizing the results and conclusions in the research related to problem-solving, several generalizations seem to be evident that indicate not only the desirability of the direct teaching of the problem-solving method, but also the need for this type of teaching. It has been concluded many times, both descriptively and experimentally, that there is a lack of the direct teaching of the problem-solving method in our schools, that students need practice in problem-solving in order to utilize the method effectively, and that science teachers approve of this method in theory, but not in practice. Thus, it would seem highly desirable that steps be taken to help teachers, and especially science teachers, to relate their theoretical

belief in the problem-solving approach to the practical application of teaching this method directly in the classroom.

The reasons for the importance of giving practice in problem-solving to the students in the classroom were demonstrated experimentally by studies that indicated that a knowledge of facts does not lead necessarily to an application of these facts, there may be little relationship between intelligence and reasoning ability or between age and reasoning ability, and there is no corresponding development in reasoning ability as the student grows older. On the other hand, while factual knowledge may aid in the explanation of phenomena, the ability to

solve problems aids the student in all types of reasoning situations.

There would seem to be little disagreement among the research people in this area of education that practice in solving problems is necessary in the curriculum of the school. Most of them deplore the lack of this type of teaching, and most of them point out or imply that we are cheating school children, and consequently future generations, by not equipping students to solve problems effectively.

After the reasons for the importance of teaching by the problem-solving technique are considered, there arise three questions which should serve as a statement of the problem under consideration:

1. What attitude is expressed by science teachers toward the teaching of problem-solving as a desirable objective of the science course?
2. What methods do science teachers indicate that they use in teaching problem-solving skills?
3. What methods do science teachers actually use in teaching problem-solving skills?

THE QUALITATIVE TECHNIQUES

It was decided that observations of classroom situations in selected high school science classes would be an effective technique to use in evaluating the kinds of direct teaching of the problem-solving procedure that might be found in public schools in Michigan. Arbitrarily, twenty observations were scheduled: twelve biology classes, four chemistry classes, and four physics classes. Equally arbitrarily, three biology classes, one chemistry class, and one physics class were selected in schools of four sizes: schools with enrollment of under five hundred, schools with enrollments of from five hundred to one thousand, schools with enrollments of from one thousand to two thousand, and schools with enrollments of over two thousand.

These schools were selected not only on the basis of size, but also on the basis of geography. It was felt that the best way to ensure cooperation for the study was to

make contact with the schools and teachers involved through a member of the faculty of Michigan State University stationed in the vicinity. This faculty member was, in some cases, a Resident Coordinator of Student Teaching, and, in other cases, the director of a Continuing Education Center. Either responsibility would put the faculty member in a position of being able to judge the teachers of the community concerning their desirability as subjects for the study. These men were asked to select and contact science teachers of average ability who might seem to reflect in their teaching the normal procedures and educational philosophy of the school in which they taught.

Observations were made at twelve different schools: four with enrollments of under five hundred, three with enrollments of between five hundred and one thousand, three with enrollments of between one thousand and two thousand, and two with enrollments of over two thousand. Within each group, no two schools were less than twenty-five miles apart, geographically speaking, but all were within a radius of one hundred miles of the state capital, Lansing. By not observing in a wider range than this, certain problems were avoided, such as differences in regional attitudes toward education in general, differences in courses of study, and differences in salary schedules of teachers.

Inasmuch as the teachers observed were carrying on a discussion session at the time of the observation, mere notetaking of what was said and done was not sufficient. A tape recorder was taken into the classrooms and notes of various observable behavior were integrated into the stenographic transcription of the class discussion. The chief reason for the use of the tape recorder was that most of the lists of problem-solving behaviors concern themselves almost exclusively with behaviors that are orally verbal, including few that are non-verbal in character. Because of this fact, word-for-word transcriptions, with appropriate notations of non-verbal behavior relating to the problem-solving process, seemed to be the

most effective way of carrying out the observations.

No observation in the classroom is completely effective unless the observer enters the situation with a knowledge of what it is that he might see in the classroom. Forty-four items concerning teachers' practices in teaching directly the problem-solving method to students were outlined by Obourn in an "Inventory of Problem Solving Practices."¹

From this inventory, a check list was formulated, changing the phrasing of the items so that the attention of the observer was transferred from the teachers' activities in the direct teaching of problem-solving to the behavioral characteristics of the students with regard to the activities of the problem-solving procedure. The items on the check list follow:

A. Sensing and Defining Problems:

1. Do your pupils sense situation involving personal and social problems?
2. Do your pupils recognize specific problems in these situations?
3. Do your pupils isolate the single major idea of a problem?
4. Do your pupils state problems as definite and concise questions?
5. Do your pupils pick out and define the key words as a means of getting a better understanding of the problem?
6. Do your pupils evaluate problems in terms of personal and social needs?
7. Are your pupils aware of the exact meaning of word groups and shades of meaning of words in problems involving the expression of ideas?
8. Do your pupils have overview lessons to raise significant problems?
9. Do your pupils discuss possible problems for study?
10. Do your pupils ask for personal interviews about problems of individual interests?

B. Collecting Evidence on Problems:

1. Do you have a wide variety of sources of information?
2. Do your pupils develop skill in using reference sources?

3. Do your pupils develop skill in note taking?
4. Do your pupils develop skill in using reading aids in books?
5. Do your pupils evaluate information pertinent to the problem?
6. Are the pupils able to use laboratory demonstrations for the collecting of evidence on a problem?
7. Do the pupils perform controlled experiments for collecting evidence on a problem?
8. Do your pupils develop skill in interviewing to secure evidence on a problem?
9. Do your pupils use community resources in securing evidence on a problem?
10. Do your pupils use visual aids in securing evidence on a problem?
11. Are the pupils' abilities for collecting evidence on a problem evaluated as carefully as their knowledge of facts?

C. Organizing Evidence on Problems:

1. Do your pupils develop skill in arranging data?
2. Do your pupils develop skill in making graphs of data?
3. Do your pupils make use of deductive reasoning in areas best suited?
4. Do your pupils have opportunities to make summaries of data?
5. Do your pupils distinguish relevant from irrelevant data?
6. Do your pupils have opportunity to make outlines of data?
7. Are the pupils' abilities for organizing data evaluated as carefully as their knowledge of facts?

D. Interpreting Evidence on Problems:

1. Do your pupils select the important ideas related to their problems?
2. Do your pupils identify the different relationships which may exist between important ideas?
3. Do your pupils see the weaknesses and consistencies in data?
4. Do your pupils state relationships as generalizations which may serve as hypotheses?
5. Are the pupils' abilities in interpreting evidence evaluated as carefully as their knowledge of facts?

E. Selecting and Testing Hypotheses:

1. Do your pupils judge the significance or pertinence of data for the immediate problem?
2. Do your pupils check hypotheses with recognized authorities?
3. Do your pupils make inferences from facts and observations?
4. Do your pupils devise controlled experiments suitable for testing hypotheses?
5. Do your pupils recognize and formulate

¹ Ellsworth S. Obourn, *An Analysis and Check List on the Problem-Solving Objective, A Science Teaching Service Circular, Circular 481* (Washington: United States Department of Health, Education, and Welfare, 1956).

- assumptions basic to a given hypothesis?
6. Do your pupils recheck data for possible errors in interpretation?
 7. Are the pupils' abilities for selecting and testing hypotheses evaluated as carefully as their knowledge of facts?

F. Formulating Conclusions:

1. Do your pupils formulate conclusions on the basis of tested evidence?
2. Do your pupils evaluate their conclusions in the light of the assumptions they set up for the problem?
3. Do your pupils apply their conclusions to new situations?
4. Are the pupils' abilities for formulating conclusions evaluated as carefully as their knowledge of facts?

The check list as outlined above was taken into the classrooms by the observer at the time of the observation, and a tally was made of the instances of observed behavior of students with regard to the items on the list.

Obviously, some of the items on the check list were unobservable: for example, the items concerning the evaluation of the students in the area of how well they select and test hypotheses. In order to secure information on these items, each of the observed teachers was asked to fill out a check list in private, indicating whether his students exhibited this behavior always, almost always, occasionally, seldom, or never. In this way, more complete data were obtained and also there was a check on the validity of the returns of questionnaires in the quantitative approach, to be discussed in the next section of this report.

THE QUANTITATIVE TECHNIQUES

In essence, the technique of this method of obtaining data was the classifying of the results of the questionnaires that were sent to one hundred ninety-two science teachers in the state of Michigan. The items checked and the degree of behavior indicated were tabulated grossly and then broken down by sizes of schools, types of schools, academic and professional education backgrounds of teachers, length of time of professional experiences, and class and extra-class loads of the teachers responding.

The questionnaire described above was sent to a selected list of science teachers in the state of Michigan. The list was compiled at random by obtaining copies of the Michigan membership lists of the National Science Teachers Association and of the Central Association of Science and Mathematics Teachers, and culling the names of those whose addresses could not be found. Names were added or dropped if it were found that the teacher in question was not a biology, chemistry, or physics teacher, or if additional biology, chemistry, or physics teachers were found to be members.

The teachers were asked questions about the size and type of school, science and science education courses taken in college by these teachers, years of experience of the teachers, their teaching load, and extra-class load, in order that these items of information could serve as variables in interpreting the types of answers recorded with regard to the problem-solving behavior of their students. These items were followed by a question concerning their opinion of the value of the problem-solving approach in the school in order to shift their attention from themselves to the students concerned in the check list part of the questionnaire.

THE QUALITATIVE RESULTS

The opinions expressed by the teachers observed, as found on the questionnaire returns, were compiled in the same categories as those listed on the questionnaire: "always," "almost always," "occasionally," "seldom," and "never." These were aligned with the data compiled through the subjective opinion of the observer. Clearly, the only valid data that might be derived by observation are the number of instances of observed behavior indicating that the student was performing some of the acts related to the problem-solving process. In the following discussion, emphasis is placed upon these positive results. It was considered unfair to analyze the results of the tape recordings to discover negative data,

those instances of opportunities for the direct teaching of problem-solving that were ignored by the teacher, for three reasons. First, upon examining the transcriptions, there was found no clear-cut pattern of predominance of any given omission in methodology among the twenty classrooms. Secondly, subjective evaluation of these omissions could not be defended adequately. Finally, the rooms were visited only once, and no general idea of whether these omissions were consistent could be derived. Because of these reasons, it was felt that to report on negative data would be statistically invalid.

Fewer than half of the items on the check-list were observed in a plurality of the rooms; eighteen of the items were seen in eleven or more rooms, and twenty-six were seen in ten or fewer rooms. As shown in Table I, out of eight hundred and eighty

the column headed "occasionally" (forty-four per cent), one hundred and seventy-six in the column headed "seldom" (nineteen per cent), and eight in the column headed "never" (one per cent).

The greatest amount of observational evidence of the direct teaching of phases of the problem-solving procedure was in the area of sensing and defining problems, and the least amount of this evidence was in the area of formulating conclusions.

There was little disagreement between the teachers' responses and the observational data. In only five instances was there a clear difference of opinion: items B4, B7, D4, D5, and E4. In four of these, the teachers tended to overestimate the pupils' abilities as compared with the observer's data, and in one instance the observer tended to overestimate the pupils' abilities as compared with the teachers' data. Inas-

TABLE I
SUMMARY OF INDICATED AND OBSERVED PROBLEM-SOLVING ACTIVITIES

Section	Responses by Teachers										Seen by Observer	
	Always		Almost Always		Occasionally		Seldom		Never			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A (10 items)	11	5	59	30	98	49	32	16	0	0	125	63
B (11 items)	7	3	77	35	99	45	37	17	0	0	87	40
C (7 items)	6	4	43	30	51	36	38	29	2	1	53	38
D (5 items)	5	5	24	24	51	51	20	20	0	0	48	48
E (7 items)	0	0	44	31	59	42	31	23	6	4	48	34
F (4 items)	6	8	35	43	29	37	10	12	0	0	25	31
Total	35	4	282	32	388	44	167	19	8	1	376	43

possible chances for observing the individual items, only three hundred and seventy-six were in evidence: a matter of forty-three per cent of possible observations. Out of the eight hundred eighty checks made by the classroom teachers, thirty-five were in the column headed "always" (four per cent), two hundred and eighty-two in the column headed "almost always" (thirty-two per cent), three hundred and eighty-eight in

much as in only eleven per cent of the cases was there disagreement, it would seem that the answers of the teachers to the check list items tended to be truthful.

THE QUANTITATIVE RESULTS

As stated previously, one hundred and ninety-two questionnaires were sent to science teachers in the state of Michigan. The

number of returns for these questionnaires was one hundred and forty-two, or approximately seventy-four per cent. A total tally was made of the responses on items A1 through F4 of the check list, and individual tallies were made in the following categories: (1) size of school (under five hundred, five hundred to one thousand, one thousand to two thousand, and over two thousand), (2) number of science areas in which the teacher had had college credit (one to three areas, four or five areas, and six to eight areas), (3) number of science education courses taken by the teacher (zero to one, two or three, and four to six), (4) number of years of teaching experience (one to five, six to fifteen, and sixteen and over), and (5) the predominant teaching area (biology, chemistry, or physics). The tallies were converted into percentages. The question regarding extra-class activities brought too many diverse answers to be synthesized, and the question on the teach-

ers' attitude toward problem-solving was ninety-nine per cent affirmative.

As pointed out in Table II, the total percentages of frequency of activities was four per cent "always," thirty-two per cent "almost always," forty-seven per cent "occasionally," sixteen per cent "seldom," and one per cent "never." All of the categories of teachers emerged, in a totality, with approximately equal percentages of frequency of activities.

In reviewing the six areas of problem-solving as mentioned in the questionnaire, all of the categories of teachers tended to remain at a level of frequency of activities which reflected the average percentage of the group as a whole, with four exceptions. Teachers in schools of over two thousand students and teachers with one to three science areas in their backgrounds tended to rate their frequency as somewhere between average and lower than the rest of the group. Teachers in schools with from five

TABLE II
SUMMARY OF INDICATED PROBLEM-SOLVING ACTIVITIES
Percentage of Responses to Items A1-F4

Category	Always	Almost Always	Occasionally	Seldom	Never
Total	4	32	47	16	1
Size of school:					
under 500	4	30	46	18	2
500-1000	4	35	46	14	1
1000-2000	4	31	44	19	2
over 2000	3	32	51	13	1
Number of science areas studied by teacher:					
1-3	3	34	40	21	2
4-5	5	34	44	15	2
6-8	3	31	52	13	1
Number of science education courses:					
0-1	4	27	44	22	3
2-3	3	33	48	15	1
4-6	5	34	48	12	1
Years of experience:					
1-5	4	31	45	18	2
6-15	4	28	47	19	2
over 15	3	35	49	12	1
Predominant area:					
biology	4	31	47	17	1
chemistry	3	29	47	19	2
physics	4	38	46	11	1

hundred to one thousand students and physics teachers tended to rate their frequency between average and higher than the rest of the group.

CONCLUSIONS

It has been ascertained that the questionnaires were completed truthfully, that the teachers contacted basically regarded problem-solving as a worthy objective of the high school science course, and that, judging by the small percentage of answers in the "never" category, this selected group of science teachers in Michigan make an attempt to provide problem-solving activities for their students. The conclusions drawn from this study can be divided into three categories: those with regard to the background and experience of the teachers, those with regard to the frequency of problem-solving activities, and those with regard to the statement of the problem.

Background and Experience of the Teachers

It has been found that within the group questioned, background and experience count for little in judging the extent of the direct teaching of problem-solving that might be found in a classroom. The results and percentages of frequency of the forty-four separate problem-solving activities did not differ markedly in schools with different populations. Although the several items on the questionnaire relative to both scientific and library equipment and materials might be assumed to weight the reactions in favor of the more populous school, such was not the case. Apparently the size of the school had little to do with classroom activities.

Background in subject matter seemed to make little difference in the teachers' responses. Some of the teachers had had college and university training in only one area, there were representatives from all areas and in all numbers up to eight science areas, including chemistry, physics, biology, zoology, botany, geology, astron-

omy, entomology, and meteorology, but there was essentially no difference in their percentage of responses.

There were many who had never taken a science education course in a college or university, even in their teaching field methodology. There were some who had had as many as six courses in science education, including methods of teaching chemistry, physics, biology, general science, and physical science, as well as science administration and supervision, science workshops, and science seminars. Essentially, however, there was no difference in their percentage of responses.

Years of experience in teaching science seemed to make little difference in the responses of these teachers. With a range of from one year to thirty-five years, there was found to be little difference in their percentage of frequency. The area in which they taught had little value as a variable, also. Chemistry, physics, and biology teachers basically answered with the same percentages.

Frequency of Problem-Solving Activities

When the percentages of frequency were examined, it was concluded that not enough attention is being given by the members of this group of teachers to the direct teaching of problem-solving. It has been pointed out by many writers that problem-solving must be taught directly, and it has also been pointed out that the forty-four items on the check list have been recommended as appropriate activities for the direct teaching of problem-solving. It must also be pointed out that the providing for these activities must be continuous and pervasive in the classroom of the science teacher who is dedicated to the direct teaching of problem-solving. In short, utilizing these activities "occasionally" is not enough.

In the total response, only thirty-six per cent of the science teachers questioned indicated that these activities were carried on "always" or "almost always," as against forty-seven per cent indicating "occasion-

ally" and eighteen per cent indicating "seldom" or "never." In the responses to the six aspects of the problem-solving procedure, it was found that the range was from twenty-nine per cent to forty per cent in the combined "always" and "almost always" category, but this is still not sufficient direct teaching of problem-solving on the part of a group that has gone on record as accepting the process as a worthy objective of courses in science.

The Statement of the Problem of This Study

The first problem as stated was "What attitude is expressed by science teachers toward the teaching of problem-solving as a desirable objective of the science course?" The answer to this question lay in the response to the questionnaire query: "In your opinion, is skill in problem-solving a worthy objective of a high school science course?" Ninety-nine per cent of the teachers having answered this in the affirmative, it was concluded that the science teachers consulted approved of problem-solving as an objective of a high school science course.

The second problem was stated: "What methods do science teachers indicate that they use in teaching the problem-solving skills?" Inasmuch as more than half indicated that they used all of the forty-four methods that were to be found in the questionnaire at least "occasionally," it was concluded that these Michigan science teachers use this methodology, at least to some extent.

The third problem, as stated, was "What methods do science teachers actually use in teaching problem-solving skills?" It was concluded, on the basis of the data, that these science teachers use all of the methods mentioned in the questionnaire, but basically do not use them enough.

General Conclusions

It was deduced that the selected group of Michigan science teachers did not truly

understand the definition of problem-solving. Inasmuch as one of the integral parts of the methodology related to this process in the schools is continuity, and there was virtually no evidence of this continuity, it would appear that most of these teachers failed to have an appreciation of the meaning of problem-solving and their own place in the teaching of this process.

In addition, it was concluded that these teachers did not truly understand the desirability of teaching this process directly. Since the data indicated that few of the items on the check list were carried out "always" or "almost always," it followed that these teachers in general did not appreciate the need for constant direct teaching of the process.

If the teachers as a group endorsed problem-solving while failing to provide problem-solving activities in the classroom, it would seem that their knowledge of this process is either non-existent or too abstract to be applicable in the classroom. In short, the teachers either do not understand the process or do not understand that it must be taught directly, since most evidence of direct teaching appeared either accidentally or incidentally.

The implications of the above conclusions are rather startling. If the direct teaching of problem-solving is one of the chief objectives of the high school science class and it would seem that teachers in this group who had taken science education courses did no better than those who had taken no science education courses in teaching for this objective, it appears that teachers of science education classes must reevaluate their instruction in this area. In addition, since neither biology nor chemistry teachers achieved this objective with any more regularity than physics teachers, the methods teachers of all three areas seem to be at fault. It would be invalid to conclude that these methods teachers ignored the problem-solving techniques and laid no stress on these techniques in their methods courses, but in this group of science teachers it

appeared to have little effect. It can only be concluded that, although the science teachers were sufficiently taught the importance of the process as exhibited by the affirmative reaction to the question concerning the importance of problem-solving, they had not learned techniques of teaching this method directly.

Teachers of science education courses in

institutions of higher education must, therefore, scrutinize their courses to find the reasons for lack of carry-over of the problem-solving objective. In the field, administrators and teachers must re-evaluate the science offerings in the high school. The poor showing by this group of science teachers relative to this objective must be corrected.

SIXTH ANNUAL REVIEW OF RESEARCH IN SCIENCE TEACHING

ELLSWORTH S. OBOURN

Specialist for Science, U. S. Office of Education, Washington, D. C.

AND

CLARENCE H. BOECK

Professor of Science Education, University of Minnesota, Minneapolis, Minnesota
General Chairmen

INTRODUCTION

WHAT research in the teaching of science was completed between July 1956 and July 1957? What findings and conclusions resulted from these studies? What implications do these findings have for the improvement of science teaching in the schools? In what areas was the research during this period concentrated? What important areas appeared to be neglected? What directions are indicated for further research?

To assist in getting answers to these and other questions, the U. S. Office of Education in cooperation with the National Association for Research in Science Teaching continued the annual study which has been carried on since 1950. The association maintains a standing committee to review and summarize the research. Science teaching at the elementary, secondary, and college levels is represented by separate sections on the standing committee.

The committees made a meticulous search of book, pamphlet and periodical literature for the period July 1956 to July 1957. The

issues of more than 50 magazines which have carried published research in science education were reviewed. Frequent use was also made of other sources such as the Education Index. In addition, the committee members reviewed abstracts of unpublished studies in science education which are obtained annually by the Office of Education. Inquiry blanks for these unpublished studies were mailed to over 900 institutions and individuals who have knowledge of current research work in the field of science education.

From these two sources of research studies the master list was made. The studies here reported were selected from this master list by applying a set of criteria which the National Association for Research in Science Teaching has established for the evaluation of research in science teaching.

The work of the committees was handicapped by the fact that, in both the published and unpublished studies, they were for the most part working with secondary

sources, such as abstracts and articles, rather than with original documents. The chairmen of the three committees, the chairman for the National Association, and the chairman for the Office of Education accept full responsibility for any errors of category or interpretation in applying the criteria for selecting the studies.

Some studies were eliminated by this evaluation process, because they failed to meet the criteria. It is entirely possible that these would have met the criteria if the abstracts and published articles had been prepared with that purpose in view.

AN EXAMINATION OF THE RESEARCH IN SCIENCE TEACHING

Research findings must be translated into effective action by school administrators, science consultants, and classroom teachers if they are to make an impact on the improvement of instruction. The research reported in this section has been classified first into three categories; namely, elementary level, secondary level, and college level. Within each of these categories there is a further breakdown which attempts to cluster the studies around those problems of science teaching to which they contribute.

Each study is identified by author and also by a letter and number in parentheses following the author's name. The letter indicates the particular subsection of section III (Bibliographies) of this report where the study is identified, listed alphabetically by author, and numbered. For example "Simon (E-8)" refers to item 8 in the subsection for the elementary level. In the same way, "Easter (S-4)" and "Combs (C-9)" refers to items 4 and 9 in subsections for the secondary and college levels, respectively.

RESEARCH ON THE ELEMENTARY LEVEL

Elementary Committee Members: Lilian Hethershaw Darnell, Chairman; Charles K. Arey, Clyde Brown, William Chamberlain, Willard Jacobson, Jacqueline

Buck Mallinson, Lawrence C. McClure, and Hanor Webb.

The studies reviewed by the elementary level committee were taken from the pamphlet and periodical literature of the period July 1956-July 1957, and also from the abstracts of unpublished studies collected by the U. S. Office of Education for the same period. For preliminary analysis, 13 studies were selected from these sources, 1 from the periodical literature and 12 from the abstracts of unpublished studies. This number represents a decrease from the 19 studies reported in the last survey.

Of the 13 studies, 8 met the criteria and thus qualified as research studies suitable for inclusion in the present report. Three have been classified as curriculum studies, three as learning studies, and two as teacher training.

Studies Related to the Curriculum

Cuno (E1) attempted to determine from such sources as courses of study, teachers' manuals, and textbooks in elementary science for children, what specific content materials in science to teach children in the kindergarten and primary grades (1-3).

The major problem of this study was to select the appropriate subject matter and from this to prepare learning experiences for the grades involved. Selected courses of study, elementary science textbooks, and teachers' manuals were analyzed. From the analysis the learning experiences for the children were built.

The important findings from this study were: (1) that more background material on specific concepts is needed for teachers in the kindergarten and primary grades; and (2) that more selective science concepts and related learning experiences are needed for children in these grades.

Pella and Solberg (E4) sought to determine "What can one fifth-grade class in Beloit, Wisc., learn about atomic energy?" Thirty-three fifth-grade children had instruction in atomic energy from their

regular teacher through books, TV programs, a filmstrip, and bulletin board materials; and from a professor of physics from a local college, who gave supplemental talks. The children posed certain questions about atomic energy which they wanted answered and then used the resources noted above to find the answers. The children presented reports, prepared bulletin board materials, held discussions, and constructed an apparatus to demonstrate a chain reaction.

Before starting the study and again at the close of the study, each child wrote a paper on what he knew about atomic energy. The two papers of each child were then compared.

From this study the following conclusions were drawn: (1) fifth-grade pupils are interested in atomic energy; (2) boys and girls evidenced equal interest in the study unit; (3) many differences were noted in the nature of the specific learnings achieved by individual pupils; and (4) fifth-grade pupils can learn many things about atomic energy as a result of systematic study.

Simon (E8) conducted a study to determine whether or not space travel should be taught as a topic in elementary science. This topic, because of its newness, is not generally included in textbooks for the elementary level.

The study consisted of attempts to: (1) present an understanding of problems scientists face as they attempt to conquer space; (2) identify the natural phenomena they encounter; (3) seek experiments to be used to give children an understanding of the difficulties and obstacles space scientists and space travelers face; and (4) locate sources of information in the Los Angeles area which would be helpful to the teacher in stimulating a class in a study of space travel.

The findings showed that: (1) many of the concepts involved in the study of space travel are actually the same concepts that are studied in the usual elementary science

program and only the point of reference needs to be changed; and (2) the intense interest currently expressed by elementary school pupils should be utilized by the inclusion of a space-travel unit in the science program of the elementary school.

Studies Related to Learning

The conditions under which children learn most readily and to the greatest degree continue to be a perplexing educational problem. Munter (E5) conducted a study which was designed: (1) to note and describe developmental patterns of responses to questions of a cause-and-effect nature in the field of science; and (2) to determine how children's thinking in this field develops with regard to age, experience, and formal training.

Five questions of a cause-and-effect nature in the field of science were given to 90 pupils in each of grades 3, 4, 5, and 6. The pupil responses to these questions were recorded and then analyzed qualitatively. Later these responses were qualified with scores ranging from 0 to 4, depending on their degree of correctness. These data were organized and statistically analyzed and graphic representations were made.

The findings of the study were that: (1) the correctness of a response tends to increase with the age of the children; (2) responses may differ greatly among children of the same age; (3) the correctness of responses made by an individual child varies from question to question; (4) there is no definite pattern in the type of responses among different grade levels; and (5) the depth of response tends to increase with age-and-grade level.

Garvey (E2) conducted "an investigation to determine the stability of science interests of five-hundred grade school children" in the city of Providence, R. I.

A questionnaire was constructed, using as a basis the eight "Major Science Area Concepts for the Fifth Grade," appearing in *Science Experiences in the Elementary*

School, grade 4, 5, and 6, published by the Department of Research, Providence Public Schools.

The questionnaire was administered twice in a period of 5 days to 500 fifth-grade children in 10 elementary schools (public and parochial) in various geographical and economic areas in Providence. The coefficient of correlation between the responses of the first and second administrations of the questionnaire was calculated to determine whether there was any indication of stability in children's science interests.

The Spearman rank-order coefficient of correlation was calculated to be 0.99. This is indicative of a very high stability between the choices made on the first and second applications of the test instrument. To determine whether the frequencies of response in this questionnaire investigation were significantly different from those which would result if only chance were operating, the chi-square test was applied to the results of the first administration. The results were found to be significant at the 1 per cent level. It was, therefore, considered safe to assume that some factors other than chance was operating. This other factor could be called a preference or an interest factor.

Johnston's (E3) study sought to find "the relative achievement of the objectives of elementary school science in a representative sampling of Minnesota schools."

The problems considered in the analytical survey were to determine: (1) to what extent the objectives of elementary school science were being achieved in Minnesota schools; (2) what pupil, teacher, and teaching situation factors contributed to the achievement of these objectives; and (3) what are the implications for the education of elementary teachers.

In the conduct of the study, questionnaires were sent to 478 superintendents of Minnesota elementary schools and to a proportionate stratified random sample of 87 Minnesota fifth-grade teachers. Science

activity logs were kept and submitted by a subsample of these teachers. The fifth-grade pupils were pre- and re-tested on science materials. Appropriate statistical treatment involved cluster sample analysis for estimation of population means, analysis of variance and covariance, and the "T" test of the significance of means.

The findings of the study revealed that: (1) there were significant gains between pretest and retest means on the science test in 58 of the 87 fifth-grade classes; (2) the difference between mean gains of 3 I.Q. groups (over 120, 95-115, below 90) on the pretest-retest, was not significant; and (3) the number of years of teaching experience was the only teacher or teaching situation factor which showed a statistically significant relationship on the science pretest-retest (0.05 level).

The following less-than-optimum conditions in fifth-grade science teaching were revealed by the survey: (1) the tendency to emphasize biological science at the expense of physical science; (2) the emphasis on textbook reading and discussion as a teaching method and the limited use of experimental and laboratory activities, directed observation, and research reading; and (3) the fact that pupils with high I.Q.'s did not gain significantly more on the science tests than did pupils with lower I.Q.'s.

Studies Related to Teacher Education

There are many persistent and recurring questions related to the education of teachers for elementary science. Some of these are the following: (1) What difficulties do elementary teachers encounter that prevent the elementary science curriculum from functioning as well as it should? (2) Are science courses in the teacher education departments of our colleges inadequate in that the teacher's training does not carry over and function in the classroom? (3) Is there a lack of interest? (4) Is there a lack of direction on the part of public school administrators?

A study was conducted by Piltz (E6) in this area. The purpose of the investigation was to determine what factors, in the opinion of classroom teachers, handicap science teaching in the elementary school, and what relationships, if any, exist between the aspirations of teachers and the difficulties they think they face.

A questionnaire was submitted to a random sample of elementary school teachers in an attempt to identify recognized difficulties encountered in science teaching. The reliability and validity of the questionnaire and the conclusions drawn from its use were tested by a variety of appropriate statistical techniques.

Conclusions drawn from the answers to the questionnaire were checked through personal interviews with a sample of teachers and through classroom observations and discussions. Among the major findings on teacher's beliefs were the following:

1. They were handicapped by a lack of physical facilities such as work and storage space, equipment, and utilities.
2. They were incompetent in such teaching techniques as selecting and interpreting content and developing attitudes in children—specifically, 75 per cent of the teachers had difficulty in helping children discover facts for themselves.
3. They made too frequent use of textbook reading as the primary method of instruction.
4. Those teachers with higher aspiration levels tended to teach more science but experienced the same difficulties as other teachers.
5. Their difficulties could be overcome through a better understanding of science and how to teach it.

Richardson (E7) conducted a study concerned with the need for inservice consultation assistance in upgrading the science contributions to the objectives of elementary education.

The purpose was to assess the awareness of county superintendents of schools to the need for consultation services at the local school district level for upgrading the contribution of science activities to elementary school objectives.

The procedure was to ask each of 21 county superintendents the following ques-

tions: (1) Do your county schools need more contributions of science activities in the elementary school curriculum? (2) Do you feel the need for the availability of a list of science specialists who would be willing to help at the local school district level in upgrading the science activities in the elementary school?

The findings were: (1) nineteen of the 21 superintendents answered "yes" to the first question; and (2) 18 answered "yes" to the second question.

RESEARCH ON THE SECONDARY LEVEL

Secondary Committee Members: George T. Davis, Chairman; Hubert F. Evans, Vice Chairman; Stanley B. Brown, Paul DeH. Hurd, Greta Oppe, and Samuel Schenberg.

Of the 18 studies analyzed here, 3 are related to science teachers, 3 to curriculum, 4 to teaching procedures, 2 to measurement and evaluation, and 4 to achievement in science. Two are classified as miscellaneous.

Studies Related to Science Teachers

DeLoach and Boysworth (S3) reported a study on the turnover of chemistry teachers in 52 Alabama high schools for the period 1942-53. All of the schools offered chemistry each year during those 12 years. Data were obtained from correspondence with schools and from records of the State department of education. Once obtained, the data were summarized in five tables. Some of the findings were: (1) whereas 16 teachers taught chemistry for at least 10 consecutive years in the same school, 177 teachers taught it for fewer than 2 consecutive years; (2) one hundred teachers, nearly half the total (218), taught chemistry for only 1 year during the 12-year period; and (3) of the 47 schools having just 1 chemistry teacher on the staff each year, only 7 schools had no turnover during the period; one school had 8 different chemistry teachers in 12 years.

Teachers whose field of college specialization was not science but who nevertheless were teaching science in the secondary schools of Massachusetts during the 1954-55 school year were the subject of an analytical study by Victor (S17). His purpose was to gain information about such teachers as persons and as guides to learning science. Accordingly, by means of questionnaires and interviews, he gathered taxonomic information on "converted" science teachers. He also obtained [gained] information, again by questionnaires, from their principals, and, for control purposes, from qualified science teachers throughout the state.

A total of 52 "converted" science teachers in 44 schools was studied. Questionnaires returned by their principals yielded information on 46 of them. The control group of qualified science teachers numbered 54. Statistical treatment of the responses in the questionnaires included the use of the T-test, the chi-square test, and the coefficient of correlation. Some of the findings were as follows:

1. Ten per cent of the "converted" teachers had taken no courses in science, and 25 per cent had taken just one or two semesters of any science. Since becoming "converted" science teachers, they had made little or no effort to study further in science.
2. Most of the "converted" science teachers were teaching science part-time, and were usually assigned to teach general science or biology. Their college majors generally had been social studies and physical education.
3. The "converted" science teachers did not use varied and effective instructional practices as often as the qualified science teachers. They also received less inservice training and had a lower degree of job satisfaction toward teaching science.
4. There was no difference in the extent to which both groups ("converted" and qualified) were aware of and taught for the varied objectives of science education when first beginning to teach science. Usually the "converted" science teachers were given little advance notice of their assignments to teach science.
5. The "converted" science teachers ranked methods of teaching science first in importance of help needed, while the qualified science teachers considered help in planning and

organizing class work most important. The "converted" science teachers ranked understanding science content low in importance.

6. The "converted" science teachers who received much inservice training used varied and effective instructional practices more often than those who received little inservice training.
7. The results of this study indicate that the "converted" science teachers need specific help and supervision in broadening their science backgrounds and their knowledges of techniques and methods of teaching science, in developing their abilities and skills in handling equipment and in expanding their concepts regarding the objectives of science education.

Problems and proposals connected with the supply of science teachers in New York City were investigated by Schenberg (S11). Information was obtained from a questionnaire sent to 54 academic and 31 vocational high schools on questions related to unqualified teachers of science classes, future demand for teachers, substitute teachers lacking professional study, housewives who qualify as science teachers, inducements for substitute science teachers, and the identity of each married woman who had quit the profession since 1940.

The major conclusion of this study is that New York City high schools are facing a crisis in science education today. Fourteen suggestions for remedial action were listed.

Studies Related to the Science Curriculum

Blanc (S2) made an analysis of high school biology textbooks "in order to determine the topics and areas receiving major emphasis by authors and publishers of biology textbooks for the high school level." His survey included 10 current textbooks in the field, selected at random, which carried a revision date of 1951 or later. The investigator found that, according to the 10 textbook authors, the most important areas in the field of biology were: (1) conservation of natural resources; (2) study of the human body; (3) study of flowering plants; and (4) genetics and eugenics.

The individual topics which the textbook authors emphasized most were: (1) struc-

ture and function of leaves; (2) foods and nutrition; (3) process of digestion; (4) principles of heredity; (5) physical factors of the environment; (6) inheritance in man; (7) evidence of change in evolution; (8) conservation of forests; (9) sense organs and sensation; (10) soil and water conservation; and (11) conservation of wildlife.

The mathematical processes needed in learning high school chemistry and physics were investigated by Lockwood (S7). The purpose was to evaluate the "generally accepted belief that high school students often avoid chemistry and physics because of the level of difficulty of the mathematics content in these courses."

The author examined seven chemistry texts and eight physics texts intended for the secondary level in order to determine the mathematical processes needed for an understanding of all the texts and for the successful completion of all the end-of-chapter problems and activities. A tally was then made of these processes. All the textbooks reviewed had copyright dates between 1950 and 1956. He concluded that:

1. If the primary function of the first course in algebra is preparation for chemistry and physics, then emphasis should be placed on those mathematical processes used most frequently in these courses.
2. Students successfully completing the first course in algebra have no valid reason for avoiding chemistry and physics because of the level of difficulty of mathematical content of these courses.
3. The quantitative approach to chemistry and physics probably should be retained, since deletion of mathematics from these courses would deprive the student of valuable experience in the application of mathematics to problems in chemistry and physics.
4. The assumption underlying the belief that some students avoid chemistry and physics because of the high level of mathematics content of these courses was not valid.

Duplication in learning some basic principles of physics was investigated by Wise (S18). The study was undertaken to determine whether high school pupils who completed a course in ninth-grade general science could definitely increase their under-

standing of some basic principles of science by completing either a course in high school physics or a survey course in science at the junior college level. Also studied for possible duplication was the high school physics-junior college science sequence.

The area of heat was used as a sample topic in the study. After three preliminary tests were constructed and administered, a single, final test was constructed and administered to a broad sampling of students in high school general science and physics and in junior college physical sciences. An intelligence test was also given to all these students. Comparisons of the mean scores of classes were based on an analysis of variance between groups of students who had completed the various combinations of coursework in science. An analysis of covariance with the intelligence factor held constant was the basis for similar comparisons.

Wise's conclusions were the following:

1. Pupils who have completed a course in general science at the ninth-grade level may usually expect that their understandings of basic principles of physics will be increased as the result of the completion of a course in high school physics. Such an increase in understanding may not, however, be expected to accompany the completion of a physical science survey course taken at the junior college level.
2. Pupils who have both general science and physics in high school may not expect that the completion of a survey course in the physical sciences at the junior college level will add materially to their understandings of the basic principles of physics.
3. Courses offering a survey of the physical sciences at the junior college level are no more effective than are courses in general science offered in the junior high school in developing qualitative understandings of the basic principles of physics. It seems reasonable to assume that a similar situation may exist with principles from other areas of science. It follows that in planning a program of general education, the major effort to develop qualitative understandings of important principles of science need not be postponed until the college years.

Studies Related to Teaching Procedures

In an experimental study, Scott (S12) compared two methods of teaching 10th-

grade general science. Specifically, he undertook to learn how the inductive method of teaching compares with the textbook method in developing pupil abilities to apply science principles. Students in the experimental group were matched with their counterparts in a control group on the basis of tests for mental maturity, reading ability, and knowledge in science. As students in the control group were being taught science by conventional methods, those in the experimental group were induced to study and discover relations between data in order to arrive at their own generalizations. At the end of the course, a test on scientific principles was administered to all. Comparisons were made between the initial and final tests given to both groups.

Scott's major findings were the following:

1. Both groups had a higher mean score on the science test at the end of the course than at the beginning.
2. In May (at the end) the experimental group made higher scores than did the control group.
3. According to the average scores, the gain of the experimental group over that of the control group was very significant.
4. A high correlation existed between mental age and scores.
5. According to the average scores, (a) boys in the experimental group outgained girls in that group; (b) girls in the control group outgained boys in that group.
6. The percentage of members of the experimental group who correctly answered those questions which required the application of principles was higher than the percentage of members of the control group who so answered.
7. In 10th-grade general science, students taught by the inductive method made more progress than students taught by the textbook method.
8. Both methods of teaching 10th-grade general science are conducive to student growth.

Richter (S9) analyzed drawing and learning in biology. The investigator sought information on two basic questions: (1) What is the relationship between the ways in which pupils see objective materials (charts) used in biology classes and the ways in which they learn the related subject matter? (2) What is the relationship between certain drawing characteristics and

the possible personality components of the pupils? A large number of drawings of biological charts were secured from biology classes. Scores on verbal and non-verbal intelligence tests and on subject matter tests were also secured. After judges had rated the drawings for accuracy, an average accuracy score was calculated for each pupil. The author also rated all the drawings for the presence or absence of certain characteristics frequently considered as indicating aspects of personality. All data were finally analyzed by intercorrelational techniques.

Following are the findings of Richter's study were:

1. There is some correlation between the average accuracy score and the scores from achievement and intelligence tests.
2. A few specific structural characteristics appear consistently in the drawings and are reliably correlated with measures of learning, drawing accuracy, and intelligence; they may give information about possible personality components.
3. The level of reliability seems to be affected by either the drawing motif itself, by something in the drawing situation, or by emotional factors in the pupils.
4. For some characteristics, variability is more highly correlated with good performance than is consistency.
5. A few psychological characteristics are significantly correlated with learning even though there is no logical reason for a correlation.
6. The findings suggest that visual, nonverbal aspects of intelligence may be important in learning from visual aids of all kinds.
7. There is some indication that the characteristics that predispose toward success in pretests differ from those that function in posttests. The author believes that this finding should be given further study.

The effects of using biographical sketches in teaching high school chemistry were studied by Easter (S4). By using an experimental approach to the study, he gained objective information on "whether or not classtime should be taken from the teaching of chemistry fundamentals to give attention to the activities and scientific achievements of famous chemists." Two comparable groups of students were given

instruction in chemistry similar in all respects, except that for the experimental group men and events in chemistry were emphasized by the presentation of biographical sketches.

Evaluated in this study was achievement related to the following six objectives: (1) fundamentals of chemistry; (2) men and events in chemistry; (3) scientific method; (4) scientific attitude; (5) scientific interest; and (6) science activities and ambitions. For five of the six objectives, the exception being the objective of scientific interest, mean differences between the experimental and control groups were tested by the analysis of covariance technique. The I.Q. and geometry scores were control variables in the analysis of covariance tests of significance, and stratification was on the basis of sex.

The author contends that "it was demonstrated by this study that an increased emphasis upon biographical sketches results in an increase of: (1) achievements in knowledge of fundamentals of chemistry; and (2) achievement in knowledge of men and events in chemistry. This study did not demonstrate that an increased emphasis upon biographical sketches results in an increase in: (1) achievement in scientific method, (2) scientific attitude, (3) scientific interest, or (4) science activities and ambitions.

Simendinger (S14) gathered experimental evidence on the ability of students to identify and evaluate assumptions in science. Her purpose was twofold: (1) to determine the effectiveness of two teaching techniques upon growth in the ability of eighth-grade pupils to identify and evaluate science assumptions; and (2) to compare growth in this ability with growth in the ability to recognize non-science assumptions and with growth in general problem-solving ability.

Nine classes were divided into three groups and for 13 weeks were taught general science by a problem-solving method. The method for each group differed: In

group I, teacher-planned experimental exercises and assumptions were stressed; in group II, pupil-planned exercises were used and assumptions were stressed; in group III (control), teacher-planned exercises were utilized, with no emphasis on assumptions. Pre- and end-tests in subject matter were given to each group in order to measure general problem-solving ability, the ability to identify science assumptions, and the ability to evaluate them. The gains were treated statistically through analysis of variance, using levels of I.Q. and sex as predictors and the teaching method as the variable. This analysis resulted in a three-by-three-by-two factorial design.

Simendinger's conclusions follow below:

1. Unless emphasis is placed upon science assumptions, combined with pupil-planned experimental exercises, the pupils will not be aware of these assumptions.
2. As a result of stress on science assumptions, combined with either teacher- or pupil-planned experimental exercises, students will improve in their ability to recognize non-science assumptions and in general problem-solving ability.
3. A method using teacher-planned experimental exercises, stressing their assumptions, is superior to a method which also uses teacher-planned experimental exercises without the emphasis on assumptions, with regard to acquisition of subject matter.
4. No one sex or level of IQ appears generally superior to any other in any of the abilities studied.
5. A high correlation exists between the initial ability to identify science assumptions and the initial ability to evaluate them, while a marked relationship is evidenced between the developments of these abilities.

From her findings the author also noted certain implications:

1. It is possible to bring about significant growth in problem-solving ability in a normal teaching situation, without loss of subject matter.
2. Of the techniques employed, the teaching technique using most pupil participation and stressing science assumptions, yields the greatest growth in the ability to identify and evaluate science assumptions.
3. The abilities involved in problem solving, like the ability to identify and evaluate science assumptions, are distinct abilities.
4. The ability to identify science assumptions is either very closely related to the ability to evaluate them, or is identical with it.

5. Training in science assumptions does not appear to transfer automatically to nonscience assumptions.

Studies Related to Measurement and Evaluation of Achievement

By employing film slides in color, Goehring (S5) measured student abilities to solve physics problems. He set out to "construct and determine the reliability and validity of a film slide test designed to measure the ability of high school pupils to apply a scientific method of thinking to the solution of practical problems in the area of mechanics in high school physics." A preliminary test was prepared which originally included 107 film slides and 101 written items (multiple-choice type) intended to measure problem-solving ability. After a panel of judges had rated each question and picture, 27 items were selected for inclusion in the test. A synchronized tape recording was then made to present orally the problem situations pictured in the projected slides and described in the questions related to them.

A second written test (minus pictures) of 26 items was prepared in order to determine the understanding of examinees of the principles of mechanics involved in the picture test. Both instruments were further refined after being administered to 412 students. An item analysis of the picture test included computation of item discrimination indices as well as item difficulty indices. The final film-slide test contained 24 items; the final principles of mechanics test, 20 items. After further testing, a reliability coefficient for the film-slide test was computed by analysis of variance.

Goehring found that it is feasible to measure through the media of projected film slides and related written items the ability to apply a scientific method of thinking in the area of mechanics in high school physics. Further, the tests used in this study appear to be sufficiently reliable and valid for classroom use.

Mallinson (S8) reported an analytical

study of the difficulty of different types of items included in certain New York Regents Examinations. Her purpose was to identify the types of questions which students avoided or found difficult in science examinations. The questions and answers selected for study were those included in part II (essay only) of the Regents Examination for biology, chemistry, earth science, and physics given in January and June, 1949 and 1950. Each item was studied to determine its type (recall, application, etc.), popularity, and relative difficulty. The data used in this analysis were part of a larger investigation involving the review of 31,317 examination papers.

The author's findings follow:

1. In general, this analysis seems to indicate that in all subject matter areas, the items giving the most difficulty were those that require an application of facts and principles—that call for an understanding of the applications of science in everyday life. In all four areas this type of item proved both difficult and unpopular.
2. The earth science and physics examination had fewer unpopular and difficult items than the biology and chemistry examinations. This may be due, at least in part, to the fact that fewer students elect biology and chemistry and those who did elect them were in general the more able ones.
3. It would appear that science teachers might well spend more time trying to help students understand the importance of scientific facts and principles in our daily lives, and to develop in them the ability to extend and apply the knowledge they derive from their study of science. In short, teachers must help students understand relationships, rather than cause them to become mere walking encyclopedias of scientific facts.

Studies Related to Achievement in Science

Smeltz (S15) conducted a retention study in chemistry. By using a sample population of students in five public high schools, he set out to "determine to what extent the learnings of high school chemistry acquired by pupils during the 11th year of high school were retained 1 year following the completion of the course."

Information was obtained through the use of standardized chemistry tests, a test

for mental maturity, and a questionnaire. The chemistry tests were administered to 180 pupils of average intelligence, the first one before they took the chemistry course, the second when they had completed two semesters of study, and the third a year later. Achievement was measured by the differences in the raw scores of the first two tests; retention, by the differences in the raw scores in the first and third tests. Coefficients of correlation were obtained between achievement and retention, achievement and intelligence, and intelligence and retention.

The author's conclusions were these:

1. Pupils who had chemistry during the 11th grade retained approximately 68 per cent of the course information 1 year following completion of the course.
2. The amount of chemistry retained was more closely related to achievement than to intelligence; intelligence was also related to achievement.
3. College-bound pupils retained more chemistry than terminal students.
4. Pupils enrolled in physics retained more chemistry than pupils not enrolled in physics.
5. Sex was not a factor in the amount of chemistry retained.
6. There was no significant difference in the types of learnings in chemistry retained.

Shepler (S13) completed an analytical study dealing with achievement in secondary school science as related to pupils' relative preference for the field. Two complementary hypotheses were tested: (1) "On the same levels of mental ability, student accomplishment in science study increases with increase in degree of subject preference. (2) On the same levels of subject preference, student accomplishments in science increases with increase in degree of mental ability."

A total of 827 twelfth-grade students were given the *Terman-McNemar Test of Mental Ability*, the science subtest of the *Harry Durost Essential High School Content Battery*, and a specially constructed instrument requiring them to make preferential choices of activities in the following 6 scholastic fields: science, languages, mathematics, social studies, fine arts, and the

manipulative arts. The scores on these three measures were transformed into standard scores with common mean and variance. The data were analyzed in various ways, as were the scores of a special population subsample of 250 cases. The subsample members were chosen so that, in aggregate, they would form a normal distribution as to mental ability, but with chance variation as to years of science study and preference for science.

The following inferences and conclusions were made:

1. Both of the hypotheses stated above were supported in satisfactory degree.
2. As a predictor of science accomplishment in groups with heterogeneous mental ability, level of mental ability was the best indicator of level of potential accomplishment.
3. In groups homogeneous as to mental ability, level of preference for science study was the best predictor of an individual's potential accomplishment in science study for his level of mental ability.
4. Preference for science study was found to be somewhat higher with higher levels of mental ability, and higher for boys than for girls. Also, there was close correspondence between number of years of science study and level of preference for this subject.

Certain data reported in a former investigation¹ on the use of sound motion pictures in high school biology were given further study by Smith and Anderson (S16). In the former study the investigators demonstrated that there were significant differences in achievement of different ability groups as a result of the use of educational films. It was demonstrated that there was a significant difference in achievement in the same direction for a group of high ability students and a group of low ability students, and that no differences were observed in a group from the middle ranges of intelligence. Since this result appeared to be an anomaly, it served as a stimulus and point of departure for the present study.

¹ Kenneth E. Anderson, Fred S. Montgomery, Herbert A. Smith, and Dorothy S. Anderson, "Toward a More Effective Use of Sound Motion Pictures in High School Biology," *Science Education*, 40:49-50, February 1956.

The authors hypothesized that two kinds of learnings were actually involved in the performance of the students investigated: that the superiority of the top group of students over their control group was achieved as a result of exceptional performance with principle-type items (on the *Nelson Biology Test, Forms AM and BM*); whereas, the superiority of the low group over their control resulted from superior performance with fact-type items.

Accordingly, items in the standardized test were classified, where possible, as fact-type or principle-type. The examination papers for both the high group and the low group were then rescored in order to obtain a fact score and a principle score. Already available were the intelligence test scores for each of the students in the two groups. The scores obtained were processed by using the analysis of variance and covariance techniques. Pretest scores and intelligence were used as control variables.

The results of the analysis yielded statistically significant differences in favor of the experimental methods of teaching biology principles. These differences were found in both the high and low groups. The differences among the instructional methods (as evidenced by the fact sub-scores) were not, however, significant for either group. The authors concluded that "the analysis offers no support to the hypothesis that two different kinds of learning were involved."

In another study, Anderson, Page, and Smith (S1) studied "the lower and upper ends of the spectrum of academic achievement and intelligence among high school seniors for the purpose of gaining a better understanding of variability existing in groups frequently regarded as homogeneous." The specific purposes, all related to science achievement, were: (1) to determine the percentages of seniors (both boys and girls) designated as exceptional in science achievement; (2) to determine the relative contribution of schools of varying size to the exceptional groups in science

achievement; (3) to ascertain the degree of relationship existing between science achievement and achievement or ability in four other areas (mathematics, social studies, English, and intelligence) for the groups designated as exceptional in achievement or ability as measured by tests in those areas; and (4) to describe the variability in achievement or ability as measured by the tests in the four other areas of those seniors designated as exceptional in science achievement.

The authors used data on the academic achievement and intelligence of 1,445 Kansas high school seniors who had taken the *Essential High School Content Battery* and the *Terman-McNemar Test of Mental Ability, Form C*. A senior was designated as exceptional if his score on a particular test (science, mathematics, social studies, English, or intelligence) placed him in the upper or lower 10 per cent of the frequency distribution for that test. By segregating the upper and lower 10 per cents on each of the 5 tests, the authors obtained 10 exceptional groups of seniors. Five test scores, sex, and size of school were tabulated for each of the 145 individuals in each of the 10 per cent groups.

Following is a summary of the findings which were related primarily to science:

1. It is evident that, in spite of almost equal numbers of boys and girls in the original sample of 145 seniors, the upper 10 per cent group in science contained a significantly greater percentage of boys than girls: 67.6 per cent boys, as against 32.4 per cent girls.
2. Apparently, size of school was not a factor in science achievement for the exceptional groups.
3. The seniors in the upper 10 per cent group in science achievement tended to be more consistent as to achievement in the other areas tested than did the lower 10 per cent group. The correlations of the scores in the other exceptional groups for mathematics, social studies, and English with the scores in science revealed that the upper groups were more consistent in science achievement than the lower groups. The only exception was in the case of intelligence, where both correlations were significant and positive and not significantly different.
4. Perhaps one of the most surprising features

of the results was the relatively small overlap between mathematics and science. To some extent this is no doubt a function of the test which tends to emphasize the nonquantitative measures in science. Nonetheless, one might well have expected to find a considerably greater percentage of overlap.

5. The distribution of science scores for the lower groups in mathematics, English, social studies, and intelligence overlapped to some extent the distributions of science scores for the upper groups in these areas.
6. The upper group in science was more variable than the lower group as to achievement in mathematics and social studies. The reverse was true in the case of intelligence.
7. If one considers the average age of seniors at the time they took these tests to be about 17, the lower group in intelligence had deviation I.Q.'s ranging from about 63 to 89, and the upper group, from about 120 to 143. In spite of this, 52.41 per cent of the lower group achieved enough in science to place them in the lower-middle 40 per cent in science achievement and 2.76 per cent achieved enough to place them in the upper-middle 40 per cent. Also, 42.76 per cent of the upper group were sufficiently low in science to place them in the upper-middle 40 per cent in science achievement. Five seniors, or 3.45 per cent, placed in the lower middle 40 per cent in science achievement and two seniors, or 1.38 per cent, placed in the lower 10 per cent.

The same comparisons for the other four areas revealed slightly less variation for social studies, but some more variations for mathematics and English. These findings suggest that an acceptable criterion for exceptional performance in science and other academic areas must be sought outside the province of intelligence. Apparently there were forces other than intelligence at work leading to exceptional achievement in science and other areas, such as motivation, originality, and creativity.

8. The specific findings of the study point up more clearly than ever the phenomenon of individual differences in science achievement and in other academic areas, as well as the great variability within individuals. In a sense, this study documents to a considerable extent present statements of the kind of education essential in a democracy. The broadly stated purposes of education have emphasized the uniqueness of each individual and the necessity to provide for the fullest development of his potentialities. This study also gives further evidence that these ideals were soundly conceived.

Miscellaneous Studies

Outdoor laboratories used in teaching natural resource conservation were studied

analytically by Hibbs (S6). Four related problems were investigated: (1) Where are the schools which have had notable success in developing and using outdoor laboratories? (2) What are the procedures which these schools employed in procuring and developing their outdoor study areas? (3) How are the laboratories being used in teaching conservation? (4) What are some guiding principles by which other schools might develop and use outdoor laboratories?

The author acquired detailed information on the four problems by reviewing literature, conferring with school personnel, and making firsthand observations of outdoor laboratories in five States (Michigan, North Carolina, Ohio, West Virginia, and Wisconsin). From the information gained, he formulated the following 10 principles:

1. The primary function of the outdoor laboratory is to provide learning opportunities necessary for implementing a sound conservation education program.
2. The school superintendent should assume responsibility for the outdoor laboratory and provide effective leadership for its development and use.
3. The school district should provide an appropriate land area for development and for use as a laboratory (as a place) to provide conservation learning opportunities.
4. A master plan should be prepared to develop and use the laboratory area.
5. A school should provide an opportunity for school personnel, pupils, parents, agencies, organizations, and other interested individuals to participate in planning, developing, and using the outdoor laboratory.
6. A qualified faculty member should be assigned the responsibility of coordinating the conservation education program, including development and use of the outdoor laboratory.
7. Inservice training, relevant to the use of outdoor study areas, should be provided for all school personnel.
8. The outdoor laboratory should be used for its intended purposes from kindergarten through high school.
9. The principal and other faculty members should cooperate in scheduling classes to provide maximum opportunities for use of outdoor laboratory facilities.
10. Conservation instruction in the outdoor laboratory should be planned to provide max-

imum opportunities for pupil participation in direct, purposeful experiences.

Rogers (S10) made a determination of the prevalence of certain important general science misconceptions among 9th- and 10th-grade children. To do this he compiled a list of 74 science misconceptions and had a panel of judges classify each misconception in 1 of 3 ways: (1) has serious implication for the behavior of the individual; (2) has some implication for the behavior of the individual; and (3) has slight implication for the behavior of the individual. Five inventory forms were then constructed with 60 items each. One-third of the statements in each form were true in order that the students would not discover that they were being tested for misconceptions.

The forms were distributed widely among 9th- and 10th-grade science classes over the Nation, and 2,525 usable answer sheets were obtained. An item analysis was made of each misconception in the five inventory forms used at the 9th-grade level. Reliabilities of the five forms ranged from 0.745 to 0.824.

The following were some of the misconceptions which were believed by at least 50 per cent of both boys and girls in the 9th and 10th grades of the sample, and were judged by the jury as having serious or some implication concerning children's behavior:

When tobacco smoke is blown through a handkerchief, the yellow mark produced is due to nicotine.

Gasoline burns in the liquid state.

There is always a calm before a storm.

Cream is heavier than milk.

Water always boils at the same temperature.

Water always freezes when its temperature is reduced to 32° Fahrenheit.

Frost is formed usually on the outside of a window.

If you can see many stars in the sky, we will have fair weather.

The sun is the center of the whole universe.

Magnets will pick up many kinds of metal.

Artificial ice is different from natural ice.

A rattlesnake always warns before it strikes.

Those who learn slowly retain more of what they learn than those who learn fast.

Those who threaten to commit suicide seldom do.

A barking dog never bites.

When a dog is fond of a man, it shows that person to be trustworthy.

A drowning person who goes down for the third time is lost.

Women with red hair are quick tempered.

Surveys

The following seven studies are largely of a survey nature and therefore are not elaborated, but rather only listed. They deal with such aspects of science teaching as enrollments, offerings, student preferences, and teacher preparation.

DeLoach, Will S., "Chemistry and Physics Enrollments in Tennessee High Schools," *Science Education*, 41:197-199, April 1957.

Huffington, Paul E., *Enrollment Trends, Offerings, and Teacher Certification in Science and Mathematics—Maryland County High Schools*. Baltimore: Maryland State Department of Education, 1957. 16 p.

Kercheval, J. W., "Some Data on Science Instruction in Iowa High Schools," *Science Education*, 41:191-197, April 1957.

McCain, Wendell M., "A Study of the Curricular Offerings, Student Enrollments, Teacher Preparation, and Teaching Loads in Physical Science in the Public Senior High Schools of the State of Washington." (Unpublished master's thesis, University of Washington, 1956.)

Randall, Roger E., "Science Teaching in Negro High Schools in Louisiana," *Science Education*, 41:65-68, February 1957.

———, "Science and Mathematics Courses Offered in Certain High Schools of Louisiana," *Science Education*, 41:202-203, April 1957.

Schenberg, Samuel, *A Study of the Science and Mathematics Courses Elected by the 1956 Senior Class, and the Number of Seniors Who Planned to Specialize in Scientific Fields in the Academic High Schools in New York City*. New York: Board of Education, 1957. 31 p.

Shannon, Henry A. *A Picture of Science Work in 632 White High Schools of North Carolina for 1955-56*. Raleigh: North Carolina State Department of Education, 1956. 2 p.

RESEARCH ON THE COLLEGE LEVEL

College Committee Members: Edward K. Weaver, Chairman; Mervin E. Oakes, Vice Chairman; Robert A. Bullington, Donald G. Decker, Clark Huber, John C. Mayfield, Abraham Raskin, George B. Salmons, M. C. Shawver, and Nathan Washton.

This current survey of science education research at the college level covers 28 studies selected from the more than 80 which composed the original group. These 80 studies were obtained from the periodical literature and from the abstracts of unpublished studies collected by the U. S. Office of Education.

Most of the studies examined on the college level were not considered qualified for analysis in the present report. It should again be pointed out, however, that some of the excluded studies would have met the criteria if the abstracts and published articles had been prepared with the research purposes in mind.

The 28 studies in this section fall into the following classifications: 4 related to curriculum; 4 to methods and resources; 13 to teacher education; 1 to status; 2 to texts, syllabi, and courses; and 4 to science personnel.

Studies Related to the Curriculum

Combs (C9) studied the effect of certain curriculum patterns on student achievement in biology through comparing scores made by students who participated in a social studies oriented core, a science-mathematics oriented core, and a general science subject matter core, with student achievement in a "limited participation situation" (students without formal education in science). She concluded that: (1) the less education these students had in general science the higher the correlation between intelligence and achievement in biology; (2) students participating in the social science core scored higher in biology achievement than those who participated in the science-mathematics core; and (3) none of the core patterns appeared to have significant meaning for biology achievement.

Sosinsky (C23) used matched groups in "a comparison of an integrated course in general chemistry and qualitative analysis of 1-year duration with separate courses in

general chemistry and qualitative analysis in a school of pharmacy." He found that on four of six parts of a general chemistry examination, the two groups were alike in achievement; however, the group taking the standard separate courses was generally superior.

Mendenhall (C21) studied the growth of ideas leading to present-day concepts of the atom. He illustrates clearly the importance of the study of the history of scientific ideas and their place in the total intellectual history of man. He assembled a comprehensive bibliography related to the growth of the atomic concept and brought out the need for recognizing that concepts of the atom will undergo further modification and development.

Studies Related to Methods and Resources

Bainter (C3) studied "the outcomes of two types of laboratory techniques used in a course in general physics for students planning to be teachers in the elementary grades." She attempted to ascertain the relative effectiveness of the traditional and problem-solving methods of instruction. Using matched pairs of students, she found: (1) there was no difference between the two methods in teaching facts or generalizations; (2) the problem-solving method was superior in teaching the application of physics facts, principles, and generalizations in interpreting social and physical phenomena and in developing most aspects of critical thinking (although not the topic of measurement); and (3) neither the traditional nor the problem-solving method was superior in teaching the use of apparatus.

Blackshear (C4) investigated "the relative effectiveness of two methods of teaching biology." Two groups rotated between a traditional content centered method and a problem-solving or scientific method technique. The data were analyzed, using the analysis of variance and covariance, multiple correlation, and regressions.

The author's findings were the following:

1. There was no significant relationship between intelligence and the ability to use the scientific method.
2. The control group (subject or content) was more effective in applying principles.
3. No differences were detected in the relative effectiveness of the two methods.
4. There were no significant differences between the sexes in their use of the two methods or their ability to use the scientific method.
5. For effective teaching, science teachers should use a variety of methods.

Lahti (C18) studied "the efficiency of the physical science laboratory in promoting a general education objective" or more specifically, "does the use of laboratory experiments of a problem-solving nature lead to a greater ability for designing an experiment and interpreting its results?" In making comparisons of laboratory teaching, he found that the use of problem-solving situations in the laboratory was effective in teaching an understanding of the scientific method; and that out of the four methods used, the inductive-deductive method produced more learning than the other three methods.

Crooks (C10) used students in beginning college science courses as respondents. Through them, applying the Flesch scale, he found that they rated all of 20 well-known science textbooks: (1) as "dull" on 7 of the categories; and (2) as "fairly difficult" on 2 of the categories. In addition, the author discovered that all 20 textbooks offered serious reading handicaps for the students.

Studies Related to Teacher Education

Bliss (C5) conducted an opinion survey of college and high school teachers of science in regard to the preparation and certification of high school science teachers. There were 89 respondents to his questionnaire. He found: (1) a slight majority of the respondents agreed that the present 30 semester hours of required college science is sufficient preparation for teachers of general science; (2) a distinct group of the high school teachers regarded the 30 semester hours as inadequate for the preparation of

teachers in biology, chemistry, and physics; and (3) most of the respondents urged a 23-32 semester-hour requirement in each of the fields of biology, chemistry, and physics.

Brown (C6) studied the "undergraduate professional education of elementary school teachers with special emphasis on the preparation for teaching science in the elementary schools of Mitchell County, Georgia." On the basis of the returns to a questionnaire, she recommended: (1) a greater amount of study in such science fields as astronomy, entomology, and earth science; (2) more specific preservice and inservice science courses for elementary school teachers; (3) less emphasis on foreign language and history requirements in the college program for elementary school teachers; (4) more emphasis on the necessity for continuous curriculum and course revision; and (5) more emphasis on pre-teaching or professional laboratory experiences in practical situations.

Bryant (C7), in an effort to apply the "factors of effectiveness" developed in an earlier study by Warren M. Davis, used teachers who were considered to be "good teachers" of elementary school science, and discovered that, while these teachers accept the factors, few of their practices measure up to them. She found that her respondents indicated that: (1) inadequate college preparation was the most pertinent reason for default of practice; and (2) college science teachers and others responsible for the education of elementary school teachers appeared to use other factors than those prevalent in the literature to make decisions as to what will be most useful in the preparation of teachers of elementary school science.

Carlin (C8) attempted to discover "whether or not courses in chemistry and physics at the high school level contribute to success in beginning college chemistry." He found that both high school physics and chemistry contribute more to success in college chemistry than does either high school

physics or high school chemistry when taken alone.

Fleek (C11) studied courses in general college chemistry in an attempt to formulate aims for, and ways of improving, physical science courses as taught at the high school level. He concluded that many courses in general college chemistry are inappropriate for preparing prospective secondary school teachers of physical science. He urged that more emphasis be placed on integrated science courses for such teachers.

Gawley (C12), in a three-way study, developed criteria for a general methods course in science education for New Jersey secondary school teachers. A questionnaire prepared from course topic listings in college catalogs, was sent to a list of colleges and universities to ascertain actual course offerings. Later, another questionnaire, which included 116 of the same topics as the first, was prepared and sent to New Jersey secondary science teachers for rating on a numerical scale. There were 495 replies. From them the author developed a proposed course in general methods for the New Jersey teachers colleges. The other two members of the research teams, Pregger (C22) and Sutman (C26), developed criteria for a special methods course in biological science education at the same institutions.

Kruglak (C17) sought to identify, by means of a questionnaire, "what kind of cooperation with colleges do high school teachers of physics want?" He found that these teachers want such cooperative activities as joint sponsorship of science fairs, frequent meetings, more information about careers in physics, and provision for special attention to gifted students.

McIntosh (C20), in one of several evaluations of National Science Foundation academic year programs, found that:

1. A general feeling of apathy and/or antipathy pervaded the students in the institute group from time to time.
2. The feeling was increased by the rigorous lectures.
3. The original placement of most of the group

in a single class in mathematics and biology was especially assailed as arbitrary, considering the diversity of preparatory backgrounds.

4. The physics course was held in high regard, but the first-semester chemistry course was berated (although the second-semester one was judged an improvement).
5. The engineering course was considered to have missed its objective.
6. Many of the group were dubious about the second-semester mathematics course.
7. Most of the group approved the avowed aims of the program but felt that the selection methods and other aspects needed improvement. They believed, however, that another year's program would be better.

Speak (C24) studied, by means of a questionnaire, "the academic science training of Kansas secondary teachers of biology in relation to their expressed needs." He found that the teachers in class AA schools were better qualified than those in other class groups. He listed what these teachers considered to be the most needed and related courses.

Stollberg (C25) paid a personal visit to 44 colleges and universities for the purpose of making "some observations concerning the education of science teachers." More specifically, his problem was to secure answers to such questions as: (1) What are effective techniques for recruiting increased numbers of science teachers? (2) What trends exist in terms of education for problem solving? Data and question sheets were sent ahead of the visit.

The 44 institutions were scattered over the entire country. The visits, lasting for 1 or 2 days, were used for interviews with workers in science and science education. From the study, Stollberg formulated a list of pressing problems regarding the recruitment and preparation of science teachers, such as: (1) How can science teachers keep up to date? (2) How can we identify the characteristics of excellent science teaching? (3) How can the shortage of science teachers be met?

Syrocki (C27) considered the criteria for selecting, developing, and validating experience units in general biology for prospective elementary school teachers. He

formulated a list of general biological principles and validated them by using elementary school teachers as judges. He formulated criteria for the selection and development of laboratory experience with biology and validated these by using college teachers as judges. Finally, he developed a rating scale for validation.

Studies Related to the Status of Science Teaching

Adams (C1) sought to determine some of the basic changes in science teaching anticipated by science teachers. In a rather lengthy survey he placed particular emphasis on techniques of science instruction, on facilities for instruction, on provisions for superior students, and on predictions for changing trends.

Studies Related to Texts, Syllabi, and Courses in Science

Hennings (C13) prepared a monograph designed to assist the science teacher in the effective consideration of the ecological basis of conservation. He developed a procedure for organizing materials around problem areas and emphasized ecological relationships and teachers' responsibilities regarding these relationships. He also suggested the implications for teaching.

Wallin and Mayor (C28) collected information concerning "the contribution of colleges to the improvement of the teaching of science and mathematics in high schools." They sent a questionnaire to 809 4-year colleges with enrollments of over 500 each, seeking data on the following questions: (1) Are special subject matter courses offered to teachers only for graduate credit, to help them improve their competence in areas where they do not have the usual prerequisites for graduate study? (2) Are correspondence courses offered for teachers of science and mathematics? (3) Are off campus extension courses offered for teachers in these areas? (4) Is other assistance offered to high school teachers?

A total of 727 replies were received. From them, Wallin and Mayor learned the following facts:

1. 82 colleges offered subject matter graduate courses for teachers, some of the courses have no prerequisites.
2. 679 offered no correspondence courses in science or mathematics.
3. 28 offered correspondence courses in mathematics and 66 in some branch of science.
4. 39 offered correspondence courses in professional education.
5. 15 offered extension courses in astronomy, 82 in biology, 30 in botany, 33 in chemistry, 37 in geology, 113 in mathematics, 31 in Physics, 15 in physiology, 28 in zoology, and 30 in "other" fields.
6. 193 offered extension courses in professional education.
7. 495 offered no extension courses.
8. These 495 colleges offered teachers other assistance, however, as follows:
 Career guidance and help in classroom activities—419.
 Lecture series open to inservice teachers—99.
 Representatives at inservice conferences—165.
 Scholarships—99.
 Summer institutes—155.
 Workshops—182.

Studies Related to Science Personnel

Ash (C2) investigated the personality differences between college students majoring in the natural sciences and the social sciences. He used the *California Test of Personality* with which to collect the desired data. Through the use of correlation techniques, he discovered that there were no statistically significant differences between the two groups as to: (1) morale; (2) social adjustment; (3) family relations; (4) emotionality; or (5) economic conservatism.

Keller (C16) assembled a large sample of answers to questionnaires on sex and related these to certain social and physical aspects of personality. She found that misinformation about sex is widespread among college students and recommended that: (1) teacher education in nondirective techniques as one base for establishing initial permissiveness; (2) extension of programs of sex education into adult groups; and (3)

examination of the misinformation and misconceptions about sex from the anthropological and sociological viewpoints.

MacCurdy (C19) developed a scientific aptitude inventory by using a jury of experts. He then tested the validity of the Westinghouse Science Talent Search as a basis for selecting potential scientific manpower replacements. Although the author did not attest the validity of the aptitude inventory, he did report the production of a self-administered test with directions for scoring and for interpreting results.

Hoyt, Ellsworth, and Katz (C15) correlated grades in engineering physics with grades in the total engineering curriculum. They sought to identify the kinds of students enrolling in engineering physics, the extent to which performance could be predicted, and the prognostic value of such a course. The analysis, covering 439 students enrolled for 5 semesters, involved statistical computations, grades, scholastic aptitude scores, and educational histories.

Findings from the study were:

1. On aptitude tests, students in a beginning course in engineering physics made substantially better scores than the average freshman.
2. The scholastic aptitude tests did not adequately predict achievement in physics or engineering.
3. A good predictor of final course grades could be the first three quiz scores (a correlation of 0.88 was found).
4. Course grades bore a close relationship to overall grade-point averages (a correlation of 0.88).
5. Course achievement was closely related to the possibility of graduation.

INTERPRETATIONS AND RECOMMENDATIONS

The committee of the National Association for Research in Science Teaching, which provided the basic material from which this report has been assembled, surveyed all issues, July 1956 to July 1957, of approximately 50 journals that from time to time have published reports of research in the field of science education. In addition, each committee reviewed the abstracts

of unpublished studies in science education collected annually by the U. S. Office of Education from more than 900 institutions where studies in this field have been done previously.

Despite the fact that the search was as meticulous and inclusive as possible, it is probable that all studies in science education for the year involved were not located. Both the National Association for Research in Science Teaching and the U. S. Office of Education are committed to the policy of improving this service by profiting from the work of previous committees.

The interpretations, recommendations, and general considerations set forth in this section are those of the chairman of the three levels—elementary, secondary, and college—together with those of the two general chairmen, one representing the association and the other the U. S. Office of Education. Thus, to some degree the material in this section may reflect the points of view and personal biases of this group, although every possible safeguard has been used to insure maximum objectivity. For any errors of judgment or misinterpretation, the general chairmen accept full responsibility.

ELEMENTARY SCIENCE LEVEL

In attempting a critical assessment of the research in elementary science reported for the year 1956–57, one should first note that two important documents bearing on this subject have been produced in recent years. The first of these is entitled *What Research Says About Science in the Elementary School*² and the second, *Elementary School Science: Research, Theory and Practice*.³

Elementary science has been recognized as a part of the school curriculum for more

² By Gerald S. Craig, Washington: National Education Association, Department of Classroom Teachers, 1957.

³ By Maxine Dunfee and Julian Greenlee, Washington: National Education Association for Supervision and Curriculum Development, 1957.

than 100 years. Before 1925 most of the emphasis was on nature study. Beginning in the mid-1920's with the pioneer research of Craig, there has been increasing emphasis on a type of elementary science program which more nearly meets the needs of young people than was true of the traditional nature study.

With the growing acceptance of a point of view which recognized that the interpretation of the physical environment is a natural facet of the development of young children, it became more and more apparent that much research was needed to establish a sound basis for the elementary science program. In the early years of this movement many experiments were conducted, but very few were supported by adequate research data.

As the movement gained momentum and as more school districts began to put elementary science into the curriculum, it became apparent that research was needed in such areas as: (1) the purposes of elementary science; (2) the nature of the elementary science curriculum; (3) types of learning experiences in elementary science; (4) teaching materials and aids in elementary science; and (5) teacher education as related to elementary science. These areas supply a valuable base for assessing the current research in elementary science.

Over the years there has been an ever-increasing volume of studies devoted to most of the areas named above. Among these many have made significant contributions and a relatively few stand out as landmark studies. Between 1940 and 1950 there was a marked increase in the number of research studies in elementary science.

Since 1950, the interest in this area has increased a hundredfold and there has probably been more research done than in the preceding 100 years. Over the past decade much of the reported research has been directed toward: (1) curriculum content and instructional techniques; and (2) teacher education as it relates to elementary science.

The recent acceleration of interest and concern for science in the schools of America has been directed as much to the elementary as to the secondary level. Schools in increasing numbers are providing more time for elementary science as well as improved courses. School administrators, consultants as well as lay folk, are showing a quickened interest in the science program, and many State and local school systems are engaged in revisions of their courses of study.

The current activity in the revision of science offerings and content in the secondary school is creating a need for reevaluation of the instructional materials in the elementary school. The need for more specialized scientists has created a demand for better provisions for the pupil who is talented in science. This problem has sharp implications for the elementary science program as well as for research, since it has been fairly well established that young people who select scientific careers get their interests early, many of them in the last years of the elementary school.

Another factor which should influence the quality and quantity of research in elementary science is the increasing need for more science in the day-to-day lives of those who are not science specialists. As the influence of science and technology increases, the demands for more and better science both in the elementary and secondary schools will increase.

Thus it would seem reasonable to add to the listing of areas of needed research in elementary science suggested above such other areas as the following:

1. Early identification of pupils having science talent.
2. Provision for the talented pupil.
3. Development of interest in science.
4. Development of abilities in critical thinking through elemental science.
5. Development of desirable attitudes.

In the areas of elementary science research for 1955-56, 19 studies were reported for analysis. Seven of these were classified as curriculum studies, 9 as learning studies, and 3 as teacher-education

studies. The present report includes only 8 studies selected from the total of 19 located by the reviewing committee. Three of these are classified as curriculum studies, three as learning studies, and two as teacher-education studies.

A careful examination of the total 27 studies reported in this and the previous analysis reveals only a few measuring up to the critical need for research in elementary science. Among them would be those studies devoted to science principles, to the development of problem-solving abilities, and to some aspects of teacher education.

On the other hand, studies related to textbooks and supplementary references, science in girls' camps, outdoor education, courses of study and the like, while perhaps of some limited local importance, can hardly be said to contribute much toward the long-range improvement of the elementary science program.

In the current analysis the curriculum studies of Cuno (E1), Pella and Solberg (E4), Piltz (E6), and Simon (E8) appear to be worthwhile contributions to the literature. This is especially true of the last two, which seek some evidence for the feasibility of introducing the concepts of atomic energy and space travel into the elementary curriculum.

Each of the three learning studies appears to have been directed toward basic issues in the field of elementary science: Munter's (E5) toward children's thinking; Garvey's (E2) toward the stability of science interests; and Johnson's (E3) toward ascertainment of the degree of reaching objectives. It should be pointed out, however, that in the first two studies the samples were so limited as to make the general application of the findings somewhat questionable.

It would appear from this analysis that, except in a few cases, there is a need for those who are in a position to direct research in elementary science to set higher standards for the following aspects of the research: (1) The nature of the problems

to be investigated; (2) the statistical design of the studies; and (3) the rigor with which the studies are carried out.

SECONDARY SCIENCE LEVEL

The review committee brought together a total of 51 studies dealing with or related to some aspect of school science on the secondary level. Although this figure represents a considerable increase over the number of investigations considered for review last year, it is doubtful whether the increase represents a real expansion of research activity. A considerable number of studies reviewed this year were completed in the summer of 1956 before August 1; that is, before the beginning of the period currently under discussion.

Of the total studies reviewed, only 25 are included in the current report. Twenty-six studies—51 per cent of the total—were judged by the committee to be unsuited in relation to the established criteria. Eleven of these were rejected because they did not come within the limits of research as defined. The majority of rejects, however, were discarded because the studies violated various requirements of sound research. Some of them lacked orderly plans, either for securing data or for determining their validity. Some of them, in other respects sound, presented conclusions which were overstatements of the actual findings. Other studies in this group were eliminated for having attempted to prove the obvious or for having utilized selected data to prove a position long since established.

The number of investigations by academic professionals, that is, science educators employed in academic institutions, about equaled those by degree candidates. Those two categories of investigators account for nearly all the research considered.

The committee derived its material chiefly from two sources: three issues of *Science Education* and the abstracts sent to the U. S. Office of Education. Only eight re-

search reports were found in other journals, and only one of these was accepted for review. Three additional studies were reported in research bulletins of boards of education.

According to the three broad classifications of research recognized by the association, the 18 studies described in the current review may be grouped as follows: 3 experimental, 14 analytical, and 1 synthetic. The 7 survey-type studies listed at the end of the review fall, of course, in the analytical category. These status studies, dealing with enrollments, course offerings, and teacher loads, represent the dominant investigative interest during the period under review.

Regarding its review activities this year, the committee wishes to make the following observations:

1. For excellence in dealing with one or more (in some cases, all) of the following aspects of craftsmanship in educational research—choosing a significant problem, validating data, using statistical analysis, and reporting—the studies of these investigators are noteworthy: Anderson, Page, and Smith; Mallison; Simendinger; Smith and Anderson; Victor; and Wise.
2. Insofar as the studies reflect the science courses which our secondary schools actually offered during 1956-57, one can say that surprisingly little curriculum experimentation was attempted throughout the Nation.
3. Many studies are being completed which merely duplicate the work of former investigators. Some of the duplicates appear to be little more than exercises in research technique rather than serious attempts to add to our fund of information about science education.
4. If candidates for the degree in M.S., M.A., and M.Ed. are required to conduct research and write theses for their degrees, then their institutions have a responsibility to help them learn the methods of scholarly investigation and reporting.
5. Science educators speak with confidence in recommending problem-solving as a desirable teaching objective. However, experimental psychologists have encountered difficulty in identifying the many ramifications in the complex of mental activities and emotions involved in problem-solving. We in science education must use extreme care in conducting research on problem-solving in view of the complexity which has been recognized by experimental psychologists in dealing with this area.

COLLEGE SCIENCE LEVEL

Even though the National Association for Research in Science Teaching and both reviewing committees have defined and categorized science education research, an overview of the college level research reported in this survey indicates that further efforts in this direction are necessary. It must be granted, however, that college-level studies in this area do not readily lend themselves to orderly schemes of classification.

In the earlier years there was an intense fervor among such men as Curtis, Downing, Powers, Craig, Pieper, and other forward-looking science educators for systematic teacher-education research in the areas of methodology, learning theory, curriculum, and the like. These men gave systematic attention to procedures, concept and principles formation, the social implications of science, problem-solving techniques, and they even promoted the formation of bureaus and centers for research in science education. They wrote many convincing articles on the advantages and importance of research activity, both to the field and to the individual investigator. Although some of their techniques, judged by present-day standards, may appear a little bewildering, these researchers exhibited a great eagerness to invent new methods and designs. Tests, scales, experiments, statistical methods, and the like were then so new that they often assumed the major role in investigations rather than a minor role as useful tools, aids, or devices.

Much of the research reviewed for possible inclusion in this analysis does not represent improvements over those earlier efforts. There is too little awareness of the need for research involving the observation of groups, their structure, interaction, and dynamics; or of the need for research in the elements of observable behavior or appropriate methods of analysis of group data.

Review of the pertinent literature pointing to the need for an investigation is often inadequately done, if at all. Library re-

search, methods of citation, and recognition of the frontier studies are all too frequently of a casual nature and inadequate scope. The case study, as a method, especially in an anthropological frame of reference, is overlooked or absent. Also overlooked, or absent, is recognition of new techniques for analyzing data.

There is a conspicuous absence of new experimental designs, and of progressive elimination of the person-to-person matching techniques as a significant factor. There is too little research based on the assumption that research may be more effective if conducted by those responsible for putting it into action. There is great need for more emphasis, not only on what people learn but also on how they learn; for emphasis on the learner rather than on teacher techniques; for more emphasis on process and less on product and things; for greater emphasis on group research, cooperation in planning and evaluation, and unity rather than diffusion. The psychologist, statistician, and science educator must learn to work together more closely, and in a more coordinated fashion.

In a recent review of college level research in science education covering the past 20 years, Miles and Van Deventer⁴ made the following statement:

Most of the research in the teaching of college science has been for introductory courses—these studies have focused on instruction by television; the objectives of science teaching including fundamental subject matter principles, scientific methodology, and scientific attitudes; the retention of learning; sequent courses; laboratory; status, content and trends, and competencies desirable for instructors.

GENERAL CONSIDERATIONS

There appears to be considerable evidence to support the contention that, in general, the number of investigations in science education has been increasing over the past few years; yet for the past 2 years the num-

ber selected for this annual survey has decreased in every category. In 1955-56, 19 studies were reported in elementary science, 22 in secondary science, and 40 in college science. This made a total of 81 studies. The present report contains 8 studies for the elementary level, 18 for the secondary (in addition, 7 surveys were listed) and 28 for the college, making a total of 54.

The personnel concerned with the selection and evaluation of these studies are fully aware of the shortcomings inherent in the process used and, moreover, feel that the criteria cited earlier in this report may not be the best that could have been used. Granting all of the above, however, it is still difficult to understand why there should be such a sharp decline in studies reported on each level at a time when an increasing number of research studies is being conducted.

The need for good research studies in science education has never been more critical than at present, when so many organizations and agencies involved in some aspect of long-range improvement plans are seeking guidance from research findings. The pioneer researches of men like Powers, Craig, Downing, Curtis, and others have been mentioned earlier in this report. These men were deeply concerned with research on some of the broad and unresolved issues of their day. They carried on this research as a part of their academic responsibilities.

When one considers the large number of outstanding leaders in science education today who are qualified to do research, as compared with the number during the time when the men named above were active, it becomes apparent that there has been a sharp decrease in research studies from this source. An examination of the 54 studies analyzed in this bulletin will reveal that most of the studies have been done either by classroom teachers or by students writing theses. Few have been done by professors of science education.

⁴ Vaden C. Miles, and William C. Van Deventer, "Research in Teaching College Science, *College and University Bulletin*, Vol. II, No. 8, March, 1959.

Most of the studies reported appear to have been done as partial fulfillment for advanced degrees. No doubt this accounts for much of the fragmentary character of the research and for its narrow local interest and limited application.

The comments above are not to be taken as criticism of such studies. Rather, more of them should be encouraged, for they do make contributions to the solution of many local problems. It is also quite probable that the persons conducting such studies will, through their experience, be better qualified and will be stimulated to attack some of the broader problems that confront science teaching.

At a time when science and technology are becoming dominant factors in the culture, there is need that science teaching should realize its fullest potentials. And yet there is an overwhelming body of evidence to indicate that this is not now true. Millions of people are influenced by superstition and unfounded belief. Other millions are preyed upon by charlatans who seek to take advantage of the low level of scientific literacy of the public mind. Somehow science education must break through this barrier and become more functional in the lives of people. We must find the reasons why science education does not now achieve more of the outcomes which it seeks. And once we find the causes, we will need to find ways to alleviate the conditions and make the necessary improvements. This is only one area of science education, that of learning, where many deeply involved issues lie. Others could be mentioned which are of equal or greater importance. These pose the broad and significant problems for research in this field which call for the best talent that can be found in science and allied areas. The broad unresolved issues must be isolated, the cluster of problems requiring solutions must be defined, and the hypotheses must be stated and tested. Only when these steps have been taken will researchers in science education be in a posi-

tion to conduct studies which have significance for the steady improvement needed over the next decade.

RECOMMENDATIONS

Based on this analysis of the current research in science teaching and on the general considerations discussed above, the following recommendations are made by the Committee:

1. That those responsible for directing research in science education attempt to focus on studies which are most likely to result in significant findings with broad implications.
2. That those responsible for directing research in science education hold to high standards in the statistical design, in the conduct of the studies, and in the interpretation of the research data.
3. That immediate steps be taken to define the major unresolved issues in science teaching.
4. That, once these major unresolved issues are defined, they be followed by a definition of clusters of problems which must be solved in order to resolve the issues.
5. That hypotheses be proposed for testing in the solution of the problems.
6. That all available research in science education be assembled and abstracted for the years following the last such project (1939).
7. That available research bearing on the unresolved issues in science education be evaluated and that a bibliography be compiled under headings related to these issues.
8. That a comprehensive plan for coordinated research in science education be made, adopted, and put into operation throughout the country.
9. That specially designated centers for research on given issues be set up at several universities and appropriate lines of communication among them be established through a central clearing-house agency.
10. That able university scholars in the field of science education engage, in greater numbers than at present, in broad research studies as a part of their academic responsibilities.

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THE SCIENCE TEACHER'S CONTRIBUTION TO THE IMPROVEMENT OF READING

JAMES SCHIAVONE

Westview Junior High School and The Reading Clinic, Lindsey Hopkins Adult Education Center, Miami, Florida

THAT adequate skill in reading is essential for academic success is axiomatic. Reading is emphasized at every grade level. As students progress through the secondary school, the reading requirements become increasingly difficult. Each specialized subject demands specific reading skills.

Actually, every teacher is a teacher of reading. In the various scientific fields, the teacher guides his students in their reading. He provides experiences designed to develop those skills essential to the successful study of science.

Science teachers have long been aware of the fact that many students are not able to comprehend the text designed for the course. Occasionally, even some of the better students experience difficulty with the text. Studies have indicated that many texts are too far advanced. Some high school chemistry and physics books measure at college level in terms of reading difficulty. Basically, science texts vary widely in level of difficulty, although they may be designed for a particular grade.

In the average high school class, a wide range of reading ability exists among the students. While some students are well above average in reading, many are far below their actual grade level.

Through the use of cumulative record data, the teacher can gain an understanding of pupil needs. With these needs in mind, a program of reading improvement can be developed as a part of the regular science period.

Many teachers encourage students to keep a science vocabulary section in their notebooks. The learning of technical terms is requisite for the development of scientific concepts and generalizations. Reference to these words in demonstrations, experiments, and first hand experiences will aid in developing the necessary understandings.

If students are to gain knowledge from scientific articles and texts, they must be able to determine the main ideas being expressed by the author. In an effort to develop an understanding of scientific material, a study type of reading is employed. Students working below their potential may not necessarily be disinterested in the subject. A possible factor may be poor study habits. Students will welcome specific suggestions relative to an approach to the study type of reading. Particularly useful to the science teacher is Prof. Robinson's study formula, Survey Q 3R. The formula is easy to remember and will be useful in any study situation. In Survey, the student recalls what he already knows about the subject, drawing from previous experience. He can jot down his ideas in outline form. Q refers to questions. These are questions that the student would like to have answered about the subject. He can also skim the chapter looking for topic headings, thereby raising additional questions answered in the chapter. The first R refers to reading. The student reads carefully with his questions in mind. The second R refers to review. Here the student checks to see that he has the desired information. The third R refers to recite. This is the manner in which the information is to be used or presented in class for discussion and examination purposes.

Another useful skill in the reading of science materials is a method of problem solving. The student states the problem, makes an analysis of the data presented, and then takes steps to solve the problem.

The open-book test is an invaluable aid to comprehension development. The teacher can assign a chapter, or portions of a chapter as a class reading assignment. The students, using the Survey Q 3R method, would then answer questions provided by

the teacher. One or two free response questions, plus specific objective type questions, will serve as check on comprehension. The free response questions, should be designed to provoke thought relative to the paragraph, chapter, or article read. Two excellent free response questions are, (1) What did the author say? (2) What is the main idea?

Class discussion should follow the written answers. This technique, employed from time to time during the semester, provides an excellent learning situation in addition to the development of essential reading skills in science.

In developing a program of reading improvement within the content fields of science, the science teacher guides his students to a better grasp of vocabulary; specific study techniques; and a problem solving approach.

The science class should serve as a stimulus to outside reading for learning and

enjoyment. The science teacher should work with the librarian in selecting suitable material and references. Many science books are available and are written over a wide range of reading difficulty. Most fourth, fifth, and sixth grade science books and texts have a format which is not childish and therefore acceptable to retarded adolescent readers. The science teacher should consider these materials for his slow learners. There also exists a wealth of free materials supplied by various industries. Classroom quantities are usually available, and serve as an excellent supplement to the text.

Demonstrations, films, and fieldtrips, provide meaningful experiences necessary for the understanding and development of scientific concepts.

With this type of planning, the science teacher can, and does, contribute significantly to the overall improvement of reading in the total school program.

SCIENCE INTEREST GROWS *

ROBERT D. MACCURDY

Centenary College of Louisiana, Shreveport, Louisiana

THE Problem: What has been the effect of the beginning of the space age on science interest? Over a period of four years do science interests change in young people? Is there a difference in the science interests of people in different national regions? These are significant questions for teachers who would utilize student-generated interest and energy for the task of teaching science.

The Review: Thompson and MacCurdy completed a study in 1955 on "The Birth of Science Interest."¹ The details of this

* Report of a follow-up study on "The Birth of Science Interest" covering three states and the years 1955-1959.

¹ R. M. Thompson, and R. D. MacCurdy. "The Birth of Science Interest," *School and Society*, 85:2105 pp. 56-57, February, 1957.

study and technique were reported at the time. Through a series of fortunate circumstances it was possible to apply the same technique, instruments and methods on state science fair contestants in Florida during 1957 and in Utah during 1959. These data were tabulated and studied in the same manner. Thus it became possible to compare the results in three different national regions over a four year period. It also was possible to combine the responses and to thus achieve frequencies that indicate strong trends which are not limited by narrow time or geographical limits.

Certain questions were asked in an interview during the public observation time in three different state science fairs. The

responses were collected on the regular interview form and then tabulated. The tables were studied to discover any pronounced trends or general choices indicated by a high frequency of response.

The responses were reported in simple frequencies and not in percentages even though there was an even hundred students studied in each instance. It was found during the interview periods that the science fair contestants were willing and vocal conversationalists and sincerely frank in their answers. They sometimes could provide no answers and sometimes they provided several answers when only one was sought. At times they provided an "either, or" response such as "either the third or fourth grade I am not sure which." The interviewers made no judgment of predetermined tailored responses; rather all responses were accepted and trends were allowed to emerge. The impressions of the writer who studied these tables have been recorded and are reported here. In addition a summary and a tentative conclusion have been drawn from these impressions.

TABLE I
FIRST SCIENCE INTEREST

What Was Your First Science Interest?	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Pets:				
Animals	8	8	6	22
Birds	2			2
Prehistoric animals	2		1	3
Insect collection		5		5
Aquarium		3		3
Beekkeeping		2		2
Scientific toys:				
Chemistry sets	5	8	6	19
Erector sets	5			5
Microscope	4	1	2	7
Radio	2	10	6	18
Rockets and space travel	2		4	6
Magnets	2	1	1	4
Telegraph sets	2	5		7
Machines	1			1
Automobile	1			1
Water wheel	1			1
Model airplane	1	2	1	4
Steam engine	1			1
Scientific toys		2	1	3

Flashlight	1			1
Boats	1			1
Botany:				
Plants	2	2		4
Gardening	3			3
Leaves, collecting	1			1
Bacteriology	1			1
Scientific play:				
Astronomy	4	11	1	16
Nature walks or field trips	3	1	4	8
Medicine	3	3	2	8
Anatomy	2	4		6
Scouting	1			1
Electricity	1	6	2	9
Photography	1			1
First aid	1			1
Nursing	1			1
4-H Club			1	1
Dissection		2	1	3
Vitamins			1	1
Collecting (miscel- laneous)		2	9	11
Testing soil		2		2
Home experiments		1	1	1
Engineering	1			1
Water supply	1		1	2
School science:				
School			1	1
Career talks			2	2
Archaeology		1		1
Science reading	4		3	7
General science	3	1	3	7
Mathematics	3	3		6
Geology	2	6		8
Biology	2	3	5	10
Atomic Energy	1			1
Meteorology	1			1
Physics		1	3	4
Science contests	2		2	4
Science dem- onstrations	1			1
Science projects			3	3
Number of students interviewed	100	100	100	300

Impressions: The students indicated that animals, scientific toys, astronomy, chemistry sets, radios, biology and collecting were items and activities of their first science interest. There were fifty-one other items reported in varying frequency, all might be called scientific toys, pets or scientific-like play activities. Two hundred and fifty nine out of three hundred respondents reported such items. There were no apparent differences between states or years in the response to this question.

TABLE II
AGE OF FIRST SCIENCE INTEREST

At What Age Did You Experience Your First Science Interest?	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Too early to recall	4	5	7	16
1-4 years of age	1	4	3	8
5 years of age	2	3	6	11
Elementary school:				
Age 6	4	6	4	14
Age 7	10	10	9	29
Age 8	4	11	10	25
Age 9	7	7	5	19
Age 10	6	12	7	25
Age 11	9	5	6	20
Age 12	10	15	9	34
Age 13	3	7	9	19
Age 14	1	7	4	12
Secondary school	21	28	25	74
Number of pupils interviewed	100	100	100	300

Impressions: Seventy four of the three hundred respondents indicated that the first science interest occurred during the secondary school years. All others assigned it to the elementary school years. Of these latter, 171 or eighty per cent indicated that it occurred between the ages of seven to thirteen years of age. There was no apparent difference between dates or states in the response to this question.

TABLE III
OCCUPATIONAL CHOICE

What Is Your Occupational Choice Today?	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Physicist	1	15	19	35
Electronics	6	2		8
Mathematics	2	1		3
Astro-physicist	1	2	1	4
Physical science		1	1	2
Science research		5		5
Medicine	10	12	10	32
Nursing	3	1	2	6
Medical technology	2			2
Veterinary medicine	1	2		3
Pharmacist			1	1
Nutritionist			1	1
Dentistry		3		3
Engineering, unspecified	3	9	16	28
Engineering, electrical	6	13		19
Engineering, physics		3		3
Engineering, chemical	1	1		6
Engineering, civil	1	1		2
Engineering, mechanical	1	2		3
Engineering, efficiency	1			1
Engineering, rocketry		1		1

Chemistry	4	3	9	16
Biochemistry	5			5
Science, unspecified	1	4	5	10
Biologist, unspecified	2	5	1	8
Microbiology	2			2
Herpetology	1	1		2
Entomology			1	1
Marine biology		2		2
Agriculture		2	1	3
Forestry	1	2		3
Agronomy	1			1
Geology		2	4	6
Minerology			1	1
Archaeology		1	1	2
Teacher, unspecified	1		8	9
Teacher, science	5	4		9
Teacher, physical education	2	2		4
Teacher, social studies	1			1
Architect	2	1	1	4
Photographer	1			1
City planning	1			1
Art		2	1	3
Social work			1	1
Military		1		1
Brotherhood		1		1
Homemaking			1	1
Secretary	1		1	2
Accounting	1	1	1	2
Air pilot	1	1		2
Mechanic, small motor		1		1

Impressions: Three hundred respondents selected fifty one different occupations in science, engineering or allied professions as their choice. (1) physics, (2) medicine, (3) engineering (unspecified), (4) engineering (electrical), (5) chemistry, (6) science (unspecified), (7) biology, (8) teaching and (9) social activities were the items of highest frequency in selective order. In the 1955 Massachusetts study, physics was in seventh place. In the Florida 1957 study and in the Utah 1959 study it was in first place in order of frequency of selection. Florida and Utah showed a higher frequency of selection for occupations in the physical sciences than the 1955 Massachusetts respondents who were also more diversified in their occupational choices.

Impressions: Is there a relationship between first science interest and occupational choice? This question was not put to the respondents directly but to the writer it appeared a relationship could be established

TABLE IV
RELATIONSHIP BETWEEN OCCUPATIONAL CHOICE AND FIRST SCIENCE INTEREST

Occupational Choice	First Science Interest	Age	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Engineering	Radio	10, 12, 13, 14	1	5	4	10
	Motors		1			1
	River dam		1			1
	Water wheel		1			1
	Erector set		3			3
	Chemistry set	10, 11	2		2	4
	Scientific toy	6		1		1
	Telescope	10		1		1
	Telegraph set	5, 8, 9, 10		2	2	4
	Physics	15		1		1
	Steam turbine	8		1		1
	Auto motor	14		1		1
	Ship model	12		1		1
	Chemistry	9		1		1
	Rockets	6			1	1
	Science club	14			1	1
	Burglar alarm	3			1	1
	Chemistry book	12			1	1
	Biology	12			1	1
	Flashlight	4			1	1
	Career talks	11			1	1
	Plants	12			1	1
	Insect collection	12			1	1
Physics	Telegraph set	10	1		1	2
	Magnets	9, 11	1	1	1	3
	Coil and breaker	6		1		1
	Astronomy	8, 12		1	1	2
	Chemistry	7, 8		2		2
	Radio	8, 10		1	2	3
	Electric motors	8		1		1
	Rockets	4, 5			2	2
	Water toy	5			2	2
	Pets	5, 7			2	2
	Space ship	9			1	1
	Science fair	13			1	1
	Physics books	8			1	1
Medicine	Microscope	8	2	1		3
	Medicine	12, 13	1	1	2	4
	Nursing		1			1
	Physiology		1			1
	Animals	4, 6, 7, 9	1	3	2	6
	Painting animals	13		1		1
	Bacteriology	6		1		1
	Blood			1		1
	Nature lore	13		1	1	2
	Bees	13		1		1
	Experiments	8		1		1
	Flower study	4			1	1
	Books	10			1	1
	Science project	12, 15			2	2
Biology	Animal collecting		2			2
	Wild animals		1			1
	Conservation		1			1
	Raising moths	10	3	1		4
	Collecting snakes	9	1	1		2
	Collecting frogs			1		1
	Collecting fish	10, 12		2	1	3
	Collecting shells	7		2		2
	Collecting insects	5		1		1

	Collecting mammals	8		1	1
	Anatomy	12		1	1
	Medicine	13		1	1
	Pet horse	3		1	1
	Trained dog	6		1	1
Chemistry	Chemistry set	8, 9, 12	2	5	7
	Chemistry	10, 14	1	1	3
	Testing soils	15		1	1
	Make radio	12		1	1
	Microscope	8		1	1
	Test tubes	5		1	1
	Prehistoric animals	6		1	1
	Radio	14		1	1
Geology	Rock collecting	5, 7, 10	2	2	4
	Fossil collecting	7, 8		3	3
	Plants	14		1	1
Teacher	Reading science		1		1
	Astronomy	10	2	1	3
	Research project	15		1	1
	Human body	12, 13	1	1	2
	Field trips	11		1	1
	Physiology	17		1	1
	Eyes	10		1	1
	4-H Club	10		1	1
	Biology collecting	6		1	1
Agriculture	Gardening		1		1
	Horticulture		1		1
	Beekeeping	12		1	1
Archaeology	Rock collecting	5		1	1
	Making oxygen	9		1	1
	Collecting arrowheads and pottery	5		1	1
Astronomy	Airplanes	12		1	1
	Astronomy	6, 7		2	2
	Physics	15		1	1
Number of Cases			33	57	67
					157

indirectly. One hundred and fifty seven of the respondents showed a strong positive direct relationship between the first science interest and the subsequent occupational choice. Some cases showed what might be called a clear outgrowth relationship, many were exactly the same, some differed sharply in characteristics but remained in the field of science. No differences could be detected between states or the passage of time.

Impressions: The persons most closely related to first science interest are (1) teacher, (2) father and (3) self, in that order. Parents and friends followed next in order. There is a difference between the 1955 Massachusetts respondents and the 1957 Florida and the 1959 Utah respondents. The 1955 Massachusetts group

TABLE V PERSON ASSOCIATED WITH FIRST SCIENCE INTEREST				
What Person Had the Greatest Influence on Your First Science Interest?	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Teacher	15	34	35	84
Father	16	17	22	55
Self	26	9	11	46
Parents	3	11	14	28
Friend	2	9	4	15
No one	1	12		13
Mother	5	4		9
Uncle	3			3
Grandfather	2		1	3
Brother			3	3
Sister	2			2
Aunt	1			1
Scoutmaster			1	1
Books		1		1
No response	24	3	9	36
Number of pupils interviewed	100	100	100	300

selected (1) self, (2) father and (3) teacher in that order both Florida and Utah respondents two and four years later reversed the first and third choices.

TABLE VI
SCIENCE ITEMS AND ACTIVITIES AT HOME

What Science Items and Activities Were Available to You Around Your Home?	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Science books	29	92	89	210
Science magazines	35	79	78	192
Museum of Science	27	65	91	188
Keeping pets	25	65	90	180
Science on television	16	72	85	173
Gardening	22	51	88	161
Scientific toys	3	57	78	158
Camping and scouting	6	46	89	141
Summer camps	15	55	74	144
Own study or workshop	28	12	70	110
Exploring or field trips		5	82	87
Chemistry sets	20	3		23
Collecting animals	20	1		21
Erector sets	20			20
Electric train	13			13
Radio set or kit	3	9		12
Collecting (miscellaneous)	7	4		11
Microscope and telescope	6	3		9
Motors and machines	7	1		8
Construction kit	5			5
Photography	5			5
Model plane and rockets	4			4
Magnets and telegraph sets	4			4
First aid and medical kits	4			4
Insect collecting kit	1			1
Science club and fair	4			4
Number of pupils interviewed	100	100	100	300

Impressions: The respondents indicated that (1) science books, (2) science magazines, (3) museums, (4) pets, (5) science television, (6) gardening, (7) scientific toys, (8) camping or scouting, (9) summer camp, (10) own study or workshop, (11) field trips were the items of greatest frequency among home science facilities. Collecting and tinkering activities were also frequently noted. Outdoor activities were reported more frequently in the South and

the West. Science television rose in frequency of response from a minor item to a major one in four years. In Utah during the 1959 state science fair it was reported with the same frequency as science books. Massachusetts in 1955 showed a greater diversity of items and activities than Florida or Utah.

TABLE VII

SCIENCE ITEMS AND ACTIVITIES AT SCHOOL

What Science Items and Activities Did You Have Available in Your School?	Mass. 1955	Fla. 1957	Utah 1959	All Three States
Reading science books	11	100	95	206
Viewing science films	5	91	95	191
Science fairs	1	85	100	186
Plant studies	5	60	78	143
Field trips	5	67	64	136
Animal studies	2	66	65	133
Visiting lecturers	3	54	63	120
Science kits	2	45	36	83
Pet show		13	24	37
Teacher demonstration	9	2		11
Science experiments	4	5		9
Astronomy	6			6
Scientific equipment		6		6
Science hobby show	1	5		6
Pictures drawn by teacher	5			5
Nature study	5			5
Models made and used	4			4
Weather studies	3			3
Audubon Society lectures	3			3
Collecting specimens	2			2
Science film strips	2			2
Science notebooks	2			2
Insect collecting	1			1
Tree study	1			1
Aquarium	1			1
Museum visits	1			1
Science TV discussions	1			1
Science bulletin board	1			1
Reading science periodicals	1			1
Bird study	1			1
Earth formation	1			1
Terrarium building	11			11
Beekeeping	1			1
Science counseling	1			1
Number of pupils interviewed	100	100	100	300

Impressions: The respondents selected (1) reading science books (2) science films, (3) science fairs, (4) plant studies, (5) field trips, (6) animal life, (7) lectures

by experts, (8) science kits, (9) pet shows and (10) demonstrations by teachers in that order as those science facilities and activities most frequently available in their schools. Twenty four other items were noted which could be called highly individualistic and manipulative or experimental. These were reported fifty seven times out of several hundred responses. A change was noted among the three states. The items science fairs and pet shows increased in frequency of selection in Florida and Utah. A similar increase was noted in the frequency of selection of such items as science kits, science films and lectures by science experts.

Summary: To the writer the items of first science interest appears to be one of personal, solitary, sensory, wonder-provoking, and free play quality. This interest first occurs during the ages of seven to thirteen years. The occupational choices have followed a steady trend in an increasing frequency in favor of the physical sciences and a reduction of diversity in occupational choices. Nearly all occupational choices were directly related to and in the same or similar scientific category as the first science interest that occurred during early childhood. In the past four years there has been a large increase in the influence of teachers on first science interest. Items of scientific nature in the home environment appeared to be personal, solitary, sensory, free play activity or items frequently related to the local environment and climate. The influence of science on television has greatly increased in the past

four years as a factor influencing science interest. Presently it rivals the interest stimulating influence of science books. Most items and activities available to student in schools appear to be group activities demonstrated or shown by a teacher to the students. Science fairs and pet shows may be an exception.

Massachusetts contentants' responses showed a strong repeated tendency toward greater diversity of choices in activities, occupations, home science items, school science activities and the reduced influence of teacher and father on first science interest. Does this result in a larger proportion of self-directed experimenters from this region? Is the increasing influence of teachers on first science interest and the increase in school science activities of a teacher-directed group activity a healthy trend? Does a vicarious experience adequately substitute for the actual activity? The findings to date are so controversial that the writer welcomes more study on this problem by people in other areas. He will be happy to supply samples of the questionnaire used in the interviews to assist in such a project.

Conclusion: First science interest is closely related to later occupational choice and occurs most frequently in the elementary school years. It is associated with free-play with pets and scientific toys. Teachers have become more influential in the past four years and school activities are becoming more influential and concentrated on group, teacher-directed, vicarious science experiences.

JUSTIFICATION FOR THE USE OF CHEMICALS IN AGRICULTURE *

GEORGE C. DECKER ¹

University of Illinois, Urbana, Illinois

TO one who has given the matter some thought, justifying the use of chemicals in agriculture falls in the same category as elaborating upon the obvious or gilding the lily. The facts can be stated in a very few words. If the use of agricultural chemicals were to be banned tomorrow, the yield of many crops would be reduced by from 10 to 90 per cent, and surplus stocks would soon disappear. The price of most food items sold in stores would double, some would treble, while still others, notably fruits and vegetables, would totally disappear from the open markets. A detailed amplification of this statement would fill several volumes, but we shall try to develop at least a portion of the picture in the next fifteen minutes.

Broadly speaking, agriculture may be regarded as the mother of chemistry, or more correctly, agriculture from beginning to end is chemistry. In their everyday life processes, growing plants, through the mysterious phenomenon called photosynthesis, manufacture and store energy in a wide variety of chemicals—starches, sugars, fats, oils, proteins, vitamins, enzymes, hormones, and so on *ad infinitum*. Then through the complicated processes of digestion, assimilation, and metabolism, farm animals, like the chemist in his laboratory, react these compounds with others to release stored energy for work and to form still other complicated organic chemicals, some of which are so complex man has not yet been able to identify, let alone duplicate, them.

If the Creator of the universe and all plant and animal life saw fit to make physics and chemistry essential components of the natural law, why should the use of chemicals by man be considered reprehensible? As a matter of fact, it is not. One simple fact seems clear—the agricultural production and the standard of living in the various nations of the world is proportionate to their knowledge of and their use of chemicals in agriculture.

It seems probable man's first knowledge of chemistry had something to do with the properties and use of water, one of the simplest of all chemicals, a basic component in many chemical reactions, and utterly essential to the growth of plants and the survival of man and beast.

His second venture in chemistry may have involved oxidation reactions—in other words, the use of fire to produce heat or energy. Perhaps fermentation and the making of ciders, mild acids, wines, brandied fruits, kraut, etc., came next. The exact sequence in which various classes of chemicals and chemical reactions came into use in primitive agriculture is not important here. However, we should realize that the use of chemicals is not new to agriculture and that the American farmer of today uses chemicals in almost every phase of his operations.

As a matter of fact, certain classes of chemical products have become so generally accepted that the average person no longer thinks of them as specific chemicals and combinations of chemicals. For example, thousands of tons of fertilizers involving literally hundreds of combinations of so-called essential elements and their related salt radicals plus a variety of minerals and trace elements are used each year. Then, too, agriculture is reportedly the largest

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¹ Principal Scientist and Head, Section of Economic Entomology, Illinois Natural History Survey and Illinois Agricultural Experiment Station.

single industrial user of petroleum products. Gasoline, diesel fuel, lubricating oils, and greases are regarded as indispensable on practically every farm. We must note, also, that wood preservative chemicals, paints, explosives, drugs, and several other miscellaneous chemicals are in common use.

The feeding of domestic animals was once a very simple procedure. You merely gave them so much hay, silage, straw, and/or grain with little or no thought as to their chemical composition. Today it is different. Now that committees of experts, working under the auspices of the Agricultural Board of the Natural Research Council, have prepared and published bulletins setting forth the nutritional requirements for the various classes of livestock, animals on the better managed farms receive diets that are carefully balanced on the basis of the nutritive value and the chemical composition of the ingredients. As a matter of fact, competition in livestock feeding has become so great and the margin of profit so small, it has become a common practice to use feed adjuvants that enable animals to increase their efficiency in the digestion and assimilation of feed and thus give greater gains per unit of feed—in fact, such a practice is a must for those who hope to stay in the business.

In recent years another great class of chemicals, the so-called agricultural chemicals, or pesticides and related materials, have played a major role in reducing prohibitive labor costs and in the attainment of greater efficiency in agriculture. As you are all no doubt aware, in recent years this group of chemicals has been subjected to much criticism from many sources. Thus, it is upon this group that we will concentrate our attention at this time.

The average citizen takes our American standard of living, including a bountiful food supply, more or less for granted. Therefore, a brief review of the nature and magnitude of the activities of these organisms man refers to as pests becomes a necessary prelude to any attempt to justify

the use of pesticides. First, let us pause to reflect on the basic biological fact that in nature every living creature is engaged in the most ruthless competition with every other living organism upon which its interests impinge. Man, as a part of that environment, is no exception. That he has been eminently successful is evidenced by the fact that the human population of this country has risen from less than one million to over 170 million in some fifteen to twenty generations. Be that as it may, rest assured the insects, plant diseases, nematodes, weeds, rodents, and their allies have not given up the battle. Man has annihilated whole armies of his own species, *Homo sapiens*. Civilizations have come and gone. But it is doubtful if man has exterminated, except in local areas, a single one of those competing species we call pests.

The maintenance and improvement of the present nutritional status of the American public is contingent upon the continued production of an adequate food supply. Plant and animal pests rank among the foremost causes of food destruction, food deterioration, and food contamination. Hence, the absolute necessity of protecting growing crops and products from serious attack by insects, plant diseases, and other pests is recognized as essential from the standpoint of both quantity and quality of the food produced.

Cultivated crops grown in North America are attacked by over 3,000 economically important species of insects, as many plant disease agents, and unestimated numbers of nematodes, rodents, weeds, and other competitors. In 1954, the United States Department of Agriculture estimated that to offset the pest losses in agricultural production, an extra 88 million acres must be cultivated, and that losses subsequent to harvest equal the production of an additional 32 million acres. Estimates of the destruction caused by agricultural pests made independently by several other agencies range somewhere between 8 and 15 billion dollars annually—a quarter of our annual production—and

this despite the widespread use of the best control practices now available.

Here again we are confronted with the general acceptance of a completely false concept. As new and better pesticides and methods of application were developed, they were evaluated in comparison with the best procedures in current use. Completely untreated checks were seldom used, and so progress has been measured in short steps. Thus, all that science has accomplished to date in the field of pest control is largely taken for granted and generally accepted as natural or normal. Every farmer knows that in the absence of insect and disease control the commercial production of most if not all fruit and vegetable crops would be impossible. He knows also that if weeds are not controlled they will take over completely and there would be no crop production whatever. Even the metropolitan city dweller should have deduced that fact from his personal observations of what takes place when vacant lots, flower beds, lawns, or parks are neglected. Anyone who has lived or even spent much time in the country knows that when a piece of land is abandoned weeds take over and that gradually over the years it will tend to revert to its original wild and natural status.

Obviously if all efforts to control pests were to be abandoned in this country, our agricultural lands would, in so far as the modified environment will permit, revert to the conditions that prevailed prior to the advent of the white man. Under those conditions the North American continent supported a human population of about 1,000,000 souls. If we were to adopt a policy of "Let nature take its course," as some individuals thoughtlessly advocate, it is possible the experts would find disposing of the 200,000,000 surplus human beings even more perplexing than the disposition of the infamous wheat surplus.

You may well ask, "If all this is true, why all the present commotion and misunderstanding concerning pests and pest control problems?" Here again, a recapitulation of

agricultural history will help us understand the present.

When the first white men came to North America they found a race of rather primitive men living in reasonable harmony with a relatively stable environment. Under these conditions, this continent supported a population of about one million persons and provided in excess of 2,000 acres per capita. Then, as now, literally dozens of pests of all classes attacked every crop that grew and neither man nor beast escaped their ravages. In the years that followed, with agriculture on a subsistence basis and a seemingly endless supply of land available, there was plenty for all, and farmers raised only feeble objections to share-cropping with the insects and other pests. Later, as urban populations increased, each individual farmer was called upon to meet the food and fiber requirements of an ever-increasing number of individuals and to do so on an ever-decreasing number of acres per capita. This trend continued until at present we have only about ten acres per person, seven of which are classified as farm land, but only two of which are devoted to crop production.

These pressures will now intensify more rapidly because of the fact we have at last absorbed and brought into production most of the lands suitable for agricultural production. As a matter of fact, 1954 marked a turning point in our history, because then, for the first time, the withdrawal of agricultural land for use as home or industrial sites, airports, and highways exceeded the land reclaimed, and the number of acres in farms showed a decline.

Many factors have contributed to the increased prevalence and destructiveness of insects, weeds, fungi, bacteria, nematodes, and viruses during the past 100 years: (1) as farmers began to use the same fields over and over, the pests had less and less difficulty finding suitable host plants. (2) After several generations certain pests which at first rarely attacked cultivated crops developed an appetite for newly

introduced plants and became so well adapted to the new environment that they became extremely destructive. (3) The breeding of crops for increased yields, uniformity, and many other desirable characteristics, was in many instances accompanied by an increased susceptibility to one or more pests. (4) To make matters worse, the pioneers brought with them a number of insect pests previously unknown to Illinois. Still other species arrived later as undesirable immigrants from other parts of this country and even from abroad. As a matter of fact, by far the majority of our most destructive pests are of foreign origin.

We must also note that in many cases serious losses that have gone undetected for many years are considered as new problems when they are discovered and the causal agent becomes known. Then, too, we cannot overlook the fact that standards of food acceptance have been drastically raised. The modern housewife would not look twice at produce that was readily accepted 50 years ago. Actually, the products of 50 years ago would not come close to meeting present grade standards established by the United States Department of Agriculture. Much of the insect and rodent contaminated food acceptable years ago could not even move in interstate commerce under current Food and Drug laws.

In the beginning, although complaining bitterly at times, farmers generally had little choice but to rely upon nature to control the pests that were ravaging their crops and livestock. Then as losses mounted and the standards of perfection demanded by an increasingly more discriminating consuming public rose, the farmers began to clamor for governmental aid and scientific guidance in the solution of the pest control problems. The early state and federal entomologists, botanists, and crops specialists were essentially naturalists. They preached a gospel of biological and cultural pest control methods. For years such measures dominated all pest control en-

deavor, for these early officials had no other course open to them.

Diligent efforts were made and are still being made to control insects and diseases by good cultural practices. Plant pathologists and entomologists generally recommend that old crop refuse be plowed under or destroyed if pests live over the winter in it. Rotations with other crops are urged wherever possible, not only to starve out pests but also to maintain balanced fertility and to put organic matter back in the soil.

Producers of specialty and seed crops diligently search for geographical areas where certain pests are not known to occur and for fields where disease and insect pests are not likely to strike. Insofar as it is practical, farmers try to observe planting dates that will be most unfavorable for specific pests, and finally, strenuous efforts are being made to breed crops for resistance to diseases and insects. While some astounding achievements have been attained through such research, the development of resistant varieties of plants has important practical limitations. All too often the resistant varieties may prove effective against specific strains of a fungus for a limited time only. Then the fungus develops a new strain that these plants can no longer tolerate or resist. Experience has shown that a disease-resistant variety of oats or wheat will last about 10 or 15 years, at most, before a new strain of the parasitic fungus develops and attacks the variety. The introduction and dissemination of parasites, predators, and disease organisms have proved advantageous in controlling some insects but these practices have very definite limitations.

As the needs for better pest control grew and it became increasingly apparent natural and cultural control measures alone were grossly inadequate, the farmers themselves turned to the use of chemicals which showed promise. Scientists reluctantly were forced into the position of following their lead. Thus we entered an age of chemical pest control.

The large-scale practical usage of pesticides is in reality one of the important technological developments of the 20th century. While it is true that numerous nondescript concoctions of lye, lime, soap, turpentine, brine, vinegar, fish oil, and even some tobacco, pyrethrum powder, mineral oil, and arsenic were reportedly used as insecticides prior to the year 1800, the quantities of pesticides used prior to 1850 were quite insignificant. Between 1840 and 1885 sulfur and Bordeaux mixture came into use for the control of mildew on grapes in Europe. The really effective use of agricultural insecticides had its origin with the first use of Paris green to control the Colorado potato beetle in 1867. As uses for Paris green and related materials were expanded to include control of the codling moth, cankerworms, the cotton leafworm, and many other leaf-feeding species, insecticide usage increased rapidly. As one would expect, use of pesticides developed most rapidly in the case of crops with a high per-acre value, notably fruits and vegetables. Pesticide production in the United States, which had increased to a level of several million pounds annually by 1900, continued to grow steadily until near the end of World War II. Release then of many new and highly effective pesticide chemicals, developed through extensive wartime research, sent pesticide production and use skyrocketing.

The rise in pesticide usage has been closely associated with and has run parallel to advances in farm mechanization. Thus, in these days of automation and labor-saving devices, many farm managers have come to regard pesticides as chemical tools and they think of them in the same light as mechanical tools.

No one knows what would happen if the use of pesticides were to be prohibited or abandoned, but it is safe to say fruits and vegetables either would totally disappear from the market or the price of the meager quantities produced would soar to levels where they would be classed as luxuries

available only to the rich. We know from valid studies conducted over the years that apples produced without pesticide protection will be 40 to 80 per cent damaged by codling moth and 60 to 80 per cent damaged by apple scab, plus an equal or even greater degree of damage to fruit caused by innumerable other insects and diseases. To this we must add the destruction wrought by wood borers, scale insects, and other pests that result in the devitalization and eventual destruction of the trees themselves.

At this point it should be noted that loss estimates by biologists are often unjustifiably criticized by statisticians and laymen alike. They point out that at times, according to reports, insects have taken 60 per cent, diseases 50 per cent, weeds 30 per cent, and nematodes 10 per cent of a specific crop—a total of 150 per cent—and still the grower has a fair harvest. In the case of most fruit and vegetable crops, such values are not necessarily additive, e.g. many individual fruits may have been rendered unsalable by both insects and diseases and control of both would be essential to the production of a marketable crop. More important, however, is the fact that potential production for many crops is rarely if ever attained and is often unknown. Thus, we are prone to think of average annual yields as normal, and totally ignore the fact that with all pests adequately controlled, yields might be doubled, or at least greatly increased.

Let us consider the case of the lowly Irish potato. It so happens potatoes have not been successfully produced without the use of insecticides since 1867. Potato growers thought they had about attained maximum potato yields in the early 1940's, but they were unaware that the copper compounds used to repel leafhoppers and control plant diseases were depressing yields. Then with the advent of DDT and the new carbamate type fungicides which replaced the copper compounds, potato yields practically doubled in 5 years' time.

In our pastures and meadows today, as in years gone by, we frequently produce more insect protoplasm than animal weight gains per acre. In some pastures it is obvious unused weed growth exceeds the production of palatable forage. Obviously we are still share-cropping with insects and weeds. So long as surpluses prevail, this is permissible, but the day may not be far distant when such inefficiency can no longer be tolerated.

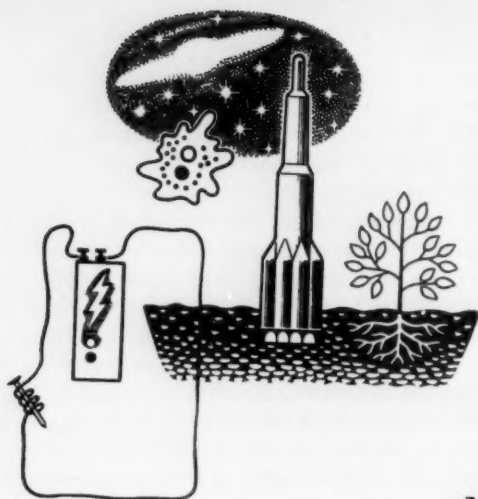
Without the benefit of pesticides, the yield of staple fiber, cereal, and forage crops could be expected to drop by from 10 to as much as 25 per cent. In two separate studies data accumulated by the United States Department of Agriculture over periods of 34 and 20 years showed that the omission of insecticide treatments reduced cotton yields 25.5 to 41.8 per cent, respectively. Agronomists at the University of Illinois have demonstrated quite conclusively that a given acre of land is able to produce about so much dry matter in any given season. Therefore, whatever is wasted in weed production must be subtracted from the crop. With weeds partially uncontrolled, crop yields would certainly be reduced, and with weeds completely uncontrolled yields would be nil.

There are those who say we should revert to the use of those partially effective control

methods used before the advent of pesticides. That is impossible. Farming has risen to the status of Big Business. Modern agricultural practices demand maximum efficiency. Unlike conditions 20 to 30 years ago, capital investments on farms today are so large the growers can no longer afford occasional complete or even partial crop failures and still stay in business. The days of the hoe, hand picking of potato bugs, and the maintenance of dusty furrow barriers for the control of chinch bugs and armyworms are gone forever.

If America wants its farmers to be reduced to the status of those in the so-called under-developed countries, the abolition of pesticides would be a logical first step.

Other speakers who will follow on this program will discuss at length residue and other hazards that may be associated with the use of pesticides. But may I say this word in justifying the continued use of pesticides. I know of no other group of chemical or mechanical tools used by so many different people under so many diverse conditions that comes even close to the safety record established in the field of pesticide usage. True, we have had our cranberry fiasco and other incidents. However, these involved minor errors in judgment and misuse. None has posed a real public health hazard.



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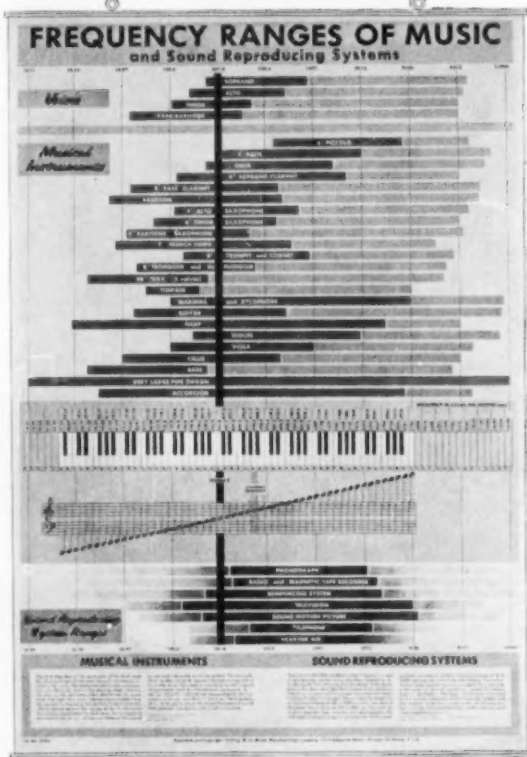
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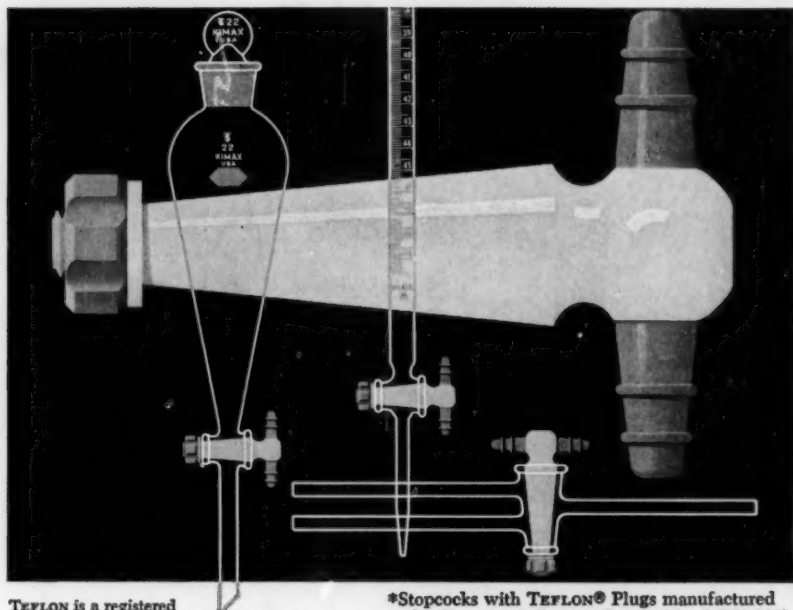
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